# SECTION FIVE
## Other Opportunities and Benefits

As should be apparent from the four preceding sections of this book, native grasses can play a role in forage production in the eastern U.S. They can also contribute in some other areas and thus provide additional benefits. As described in Chapter 2, native grasses in much of the eastern U.S. occurred in woodlands and savannahs. As such, they are a good tool for silvopasture. There also has been a great deal of interest in production of biomass from dedicated herbaceous crops for renewable energy. Among the candidate biomass crops, perhaps the one that has received the most attention is switchgrass. While reduced energy costs in recent years have shifted the focus away from cellulosic biofuels, the history of this idea has been characterized by repeated cycles of increased and then decreased interest in such crops. Therefore, renewed interest in biomass crops at some point in the future seems quite likely. Finally, there has been considerable interest in the conservation benefits of native grasses, an interest that has persisted for decades. Specifically, the benefits for wildlife conservation (including pollinators) and soil and water conservation will be addressed in this section. In both cases, though, the focus will be primarily on those benefits in the context of forage production.

## CHAPTER NINETEEN
# Native Grasses in Silvopasture Systems

With the exception of the prairies that once covered what is now the eastern Corn Belt, most of the native grasslands in the eastern U.S. have occurred in association with some tree cover. This may have been savannahs (very open sites with 2-20 trees per acre). In such situations, sunlight was able to reach most of the ground allowing for an abundant growth of native grasses and associated forbs and legumes (Chapter 18). Where fires had been less frequent and/or intense, tree cover would likely have been greater and less light would have reached the ground. These sites were "woodlands" having up to 50-60 trees per acre[31]. The definitions of savannah and woodland are not exact and the distinction between these two communities is not precise. Rather, they are simply two ends of a continuum between prairies (no tree cover) and forest (closed canopies). In woodlands, grass growth will be sparser because of the reduced amount of light reaching the ground relative to a savannah. Interestingly, plant diversity in savannahs and woodlands is actually greater than in prairies. This is because of the greater variability in the amount and pattern of light reaching the ground where partial tree cover exists[45].

## RESTORING SAVANNAHS AND WOODLANDS

One option for developing silvopasture is to simply restore degraded savannahs and woodlands. Where there has been a legacy of fire in association with open canopies, native seedbanks are often still viable. The longer the interval since elimination of prescribed fire and subsequent canopy closure, the more depleted the seedbank is likely to be. In some cases, particularly on the margins of the former prairie such as in southern Wisconsin and Michigan, relict woodlands and savannahs can still be recognized by the presence of large-crowned trees that developed under open conditions. On such sites, where fire exclusion may only go back 30 or 40 years, seedbanks can still have an abundance of native plant seed. Indeed, the native plants themselves may still be present where sunlight is adequate, such as around field edges or where forest canopy gaps yet exist. Therefore, the shorter the interval since fire exclusion, the easier the restoration to woodland or savannah conditions.

Selection of a restoration site should also take into account whether there has been any fire history at all and whether the site ever has supported a rich, grassy ground layer. Sites on northerly exposures or that have poor drainage and remain wet, particularly in late winter and early spring, typically have had less fire and, consequently, may not have a rich seedbank of grasses or forbs. And because prescribed fire will likely be important for maintaining a restored savannah or woodland, sites where burning is not practical are also less desirable for restoration.

*Basic guidelines for restoring savannahs and woodlands*

The first step in restoration is opening the canopy enough to allow light to reach the ground and encourage growth of forage. Depending on the quality of the trees present, the best way to accomplish this is a commercial timber sale. Leaving 20-40 stems per acre, depending on crown size and condition, should be the goal. Stems that are likely to survive for many years, are fire resistant (i.e., southern pine, oak, hickory) and have some prospect of increasing in value should be selected as “leave” trees. You may want to leave 10-20 percent more stems per acre than what you want as the end goal. This is because a number of the leave trees will be vulnerable to windthrow, ice damage, fire or may otherwise succumb to the stress associated with opening the site.

Once the canopy has been opened, you will have to control woody vegetation. This can involve stump removal, herbicides, prescribed fire or some combination of these practices. Stump removal is very expensive, not always necessary and will do little to control the smaller woody rootstocks of saplings. Herbicides can be effective, but care must be taken to avoid products that may damage the residual overstory either through direct contact or soil activity. Where the retained overstory is comprised of southern pines, products containing the active ingredient imazapyr are a good choice. For hardwoods, products containing triclopyr are a good option. Be aware that either of these herbicides may cause damage to some forbs that could be considered desirable. Before using either chemical, be sure that you are willing to take some risk in this regard. Burning has many benefits including removal of leaf litter and reducing logging debris, scarifying dormant seed, killing seedlings of undesirable plants and controlling small woody stems. However, a single fire will not provide complete control of woody stems, especially after many years of fire exclusion that have allowed hardwoods to become well established and develop extensive roots.

On sites with a history of fire and open canopies, the seedbank can provide ample ground cover without need for any direct seeding (Figure 19.1). Depending on the grasses that respond to the newly opened canopy, several fires over a period of 3-6 years may be needed to encourage the sun-loving, fire adapted, warm-season grasses desirable for forage (Figure 19.2). Direct seeding is an option, especially where

*Figure 19.1. Latent seedbanks in areas with a history of fire and open canopy conditions can develop rich, herbaceous understories without the need for any direct seeding. This site had been burned annually and grazed for decades until open range laws were rescinded in the 1940s. Following woodland restoration in 2000, an abundant herbaceous ground layer has developed from the seedbank. Credit, C. Coffey.*

*Figure 19.2. With adequate light and judicious use of prescribed fire, native C4 grasses, such as the big bluestem seen here, are showing up in the understory of this woodland restoration site. Note that in the background where the canopy is heavier and shade greater, there are fewer grasses.*

stumps have been removed, and can be used to augment the grass component. However, without substantial ground disturbance such as will result from stumping, a fire will be necessary to ensure a desirable seedbed, one free of litter and thatch where the seed can reach the soil. It is also important to remember that some herbicides that may have been used for control of woody species could have soil residual activity that could impair germination of any seed that you sow.

## CREATING A SILVOPASTURE

If restoration of a savannah or woodland is not an option, silvopasture can be created in two other ways — starting from a forest or from a pasture. In the first case, the process will be very similar to that described above for savannah and woodland restoration. Perhaps converting a stand of planted pines or a woodlot is the goal. In these situations, the canopy must be opened. The choice of how many trees to leave should be guided by the trade-offs between having more or fewer trees — amount of grass needed, value of timber or need for shade. Regardless of whether the number of leave trees places your site closer to woodland or savannah conditions, you must still take steps to control competing hardwood sprouts just as with woodland restoration. But unlike the restoration process described above, some seeding will almost certainly be required to provide the appropriate understory. In the case of planted pines in the Southeast, most are planted on sites previously used in row crop production. These sites have experienced heavy erosion that has long since depleted native seedbanks. Alternatively, these pines may be in the second or third rotation and/or are on sites long removed from fire and open canopies. Many woodlots and hardwood forests fall into the latter category.

The other situation, starting from a pasture condition, can work as well but will require establishment, rather than removal, of trees. Two critical considerations in establishing the trees are what species and how many to plant. In terms of species, choose those that have the potential to produce income in the future. For many parts of the Southeast, species such as shortleaf, longleaf and loblolly pine are good choices. Pines allow more light to reach the ground for a given amount of canopy cover and stem density than do hardwoods. Among hardwoods, two species that have the potential to provide substantial revenues are black walnut and cherrybark oak[9; 10; 30]. However, both require good soil quality to be productive. Thus, on poorer sites, pines are likely to be the best option. Regardless, trees must be matched to the site to ensure they are able to survive and grow to maturity at an acceptable rate.

The number of trees to be planted should take into account anticipated seedling mortality and crown size at maturity. A reasonable expectation for seedling survival is 90 percent, assuming good planting and competition control practices. Some additional stems may be lost during the stand's life, so allowing additional tree stocking at establishment can offset such losses. At maturity, having 40-60 pines and 30-50 hardwoods is reasonable. Thus, assuming no future thinning, planting 50-75 pines and 40-60 hardwoods per acre are good targets. These work out to tree spacings of 30×30 feet to 24×24 feet for the pines and 35×35 feet to 27×27 feet for the hardwoods. Where thinning is a consideration, densities could be considerably higher. Keep in mind the amount of shade resulting from the young trees with their smaller crowns is negligible for the first 5-10 years of the stand even for tree densities twice those listed above. However, the benefit of higher densities and associated thinnings will depend on the markets for the small diameter trees, largely pulpwood. With weak markets, revenues will be low and finding loggers willing to harvest the material will be difficult.

Regardless of the species or spacings you choose, seedling survival will require good competition control, especially where there is existing grass cover. Some form of protection of the seedlings from browsing is also important. Tree shelters or wire exclosures both can be effective. For the first several years post-planting, cattle access will have to be restricted to prevent damage or destruction of the seedlings. Use of prescribed fire in silvopastures will be less critical than in situations where woodland or savannah restoration is being undertaken. That is because when your starting point is a pasture, there will not be the large number of well-established rootstocks from years of woody growth as is the case with restoration projects. Fire certainly could be used with silvopasture but is not necessary under most circumstances. However, burning needs to be delayed until seedlings are large enough to survive the fire, about five years old for most southern pines (sooner for longleaf pine) and perhaps 8-10 years for the hardwoods.

*Selecting native grasses for silvopasture*

Where seeding is required, native grasses can be established in silvopastures. The choice of species to plant should match the site and your production goals as described in Chapter 6. With the tree densities described above, light conditions on the ground will allow any of the native grasses to be productive. However, as tree densities and associated shade increase, growth of the grasses can be substantially reduced. When light levels drop below about 50 percent, the production of these sun-loving species begins to decline[35]. Above 65 percent shade, production is very poor[1; 57]. In situations where shade is at the upper end of the tolerance of the native grasses, there are some options that should be considered. The wildryes and sideoats grama are species that have greater tolerance of shade and may produce more of their potential yield in silvopastures. Keep in mind though, that wildryes are cool-season species and will not produce well in summer. Sideoats grama is also somewhat shade tolerant but is much less productive than the tall species of native warm-season grasses. Finally, switchgrass, a species that is not more tolerant of shade than the other native grasses, is a good option because of its higher productivity. Switchgrass, even with a 20-30 percent penalty in yield due to shade, will produce about as much as big bluestem or indiangrass do in full sun. Along these same lines, native grasses, because of their higher yields, are still likely to outproduce the more shade-tolerant introduced cool-season species in a silvopasture setting.

*Establishing native grasses in silvopasture*

The principles for establishing native grasses in a silvopasture setting are identical to those presented in Chapters 6-8. Shallow seeding with good seed-soil contact and excellent weed control—before and after seeding—are still critical to success. Timing and seeding rates are likewise similar and no adjustments are needed. The major difference in silvopasture settings is the greater difficulty in providing a high-quality seedbed, at least where the silvopasture is being developed from an existing forest, woodlot or pine planting. In all of these situations, ground conditions may be too rough for equipment and, therefore, may inhibit creation of a clean, fine-textured and firm seedbed. In these situations, a prescribed fire that removes most of the litter and debris will be critical to allowing better seed-soil contact. If a drag of some sort or even a blade can be used to scuff-up the ground surface while knocking down mounded dirt, this will be beneficial as well. Also, ground conditions on these types of sites will likely require that seed be sown rather than drilled. Increased seeding rates are recommended for sowing (see Table 7.1). Finally, timing sowing before a good rain (or late winter snow) will help ensure better success.

## SUMMARY

Historically, the woodlands and savannahs of the eastern U.S. were dominated by native grasses. Therefore, restoring such sites can often result in good stands of native grasses and forbs simply by stimulating still intact seedbanks. In cases where the interval between fire exclusion and restoration has been more than 40-50 years, augmenting the seedbank by sowing additional seed may be necessary. Sites without a recent history of burning or open canopy conditions, such as woodlots or pine plantings, can be converted to a silvopasture. In these situations, some seeding will almost always be needed to supplement depleted seedbanks. Finally, trees can be established in existing pastures or open fields to develop a silvopasture. In all these cases, it will be critical to allow enough light to reach the ground to support vigorous growth of native grasses. A good rule of thumb is to maintain at least 50 percent sunlight reaching the ground.

CHAPTER TWENTY

# Integration of Forage and Biomass Production

Over the past several decades, a great deal of attention has been given to use of herbaceous crops for production of renewable energy. Among those crops, one that has come to the fore is switchgrass. Because of the attributes of this species described in Chapters 1 and 3—perennial, low input, high yielding and adapted to a wide range of sites—it has been considered the preferred renewable bioenergy crop. Forecasts by the U.S. Department of Energy had estimated as many as 25 million acres could be planted to switchgrass, primarily to meet demand for liquid transportation fuel[14]. While those estimates no longer seem realistic, there could be considerable interest in this species in the future if energy costs increase. In the meantime, some markets appear to be developing that can use switchgrass biomass for other purposes including pelletized fuel, bedding for dairies and other livestock operations, erosion mats and, more recently, paper plates and food service containers. Regardless of the end use, almost all these production scenarios involve a single, post-dormancy harvest of switchgrass. Such a harvest strategy minimizes fertilizer and nutrient removals, maximizes yield and reduces production costs through fewer trips across the field.

Obviously, harvesting switchgrass in winter means that forage value is extremely low. What is produced at that time of year is biomass, not forage (Figure 20.1). However, there are opportunities to extract some forage from such a system. The most obvious approach is to remove a part of the crop early in the season for forage and then allow the regrowth to go to biomass production. The forage removal can be either through grazing or a hay harvest (Figure 20.2).

*Figure 20.1. Switchgrass being grown for biomass production is normally harvested only once per year and then during late fall or winter. Here, a switchgrass stand grown for biofuel feedstock is being harvested in December for the first time all year. Such material is stemmy and has little to no value for forage. Credit, K. Goddard.*

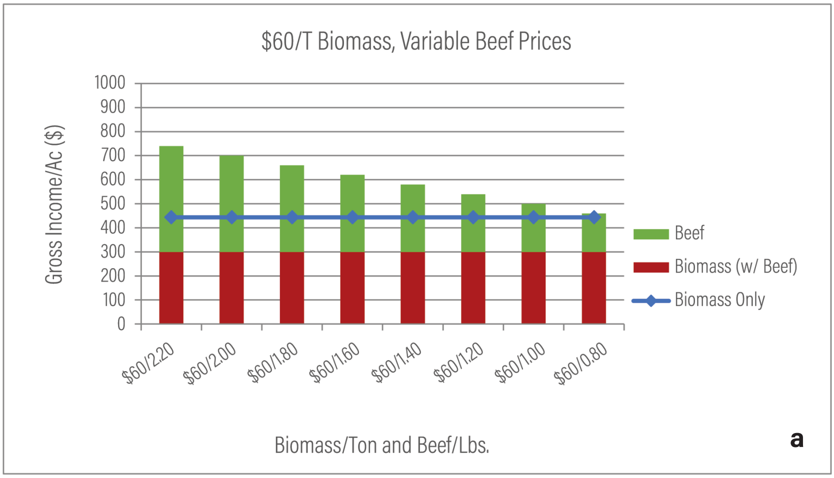

*Figure 20.2. Switchgrass being grown for biomass production can be grazed early in the season while still vegetative (a). Such material is high in nutritive value and produces excellent gains. Regrowth of grazed material can be substantial, producing 4 tons per acre by fall dormancy. This switchgrass had been grazed for 31 days up until 16 days before this picture was taken (b).*

*Grazing biomass fields*

The key to maximizing forage value from grazing switchgrass biomass fields is to start early, as soon as the stand will support grazing in spring. In a study conducted at two locations in Tennessee, grazing switchgrass with weaned steers for 30 days in spring provided 1.94 and 2.51 pounds ADG, yielding 198 and 289 pounds of gain per acre, respectively, at the two sites[3]. A similar study in Oklahoma reported 2.3 pounds ADG with 177 pounds of gain per acre for weaned steers over 30 days[40]. These are obviously substantial amounts of gain for such a short grazing interval. During this period, cool-season grasses could be rested, allowed to grow into a hay crop and, in the case of tall fescue, toxins could be avoided. The other reason to start grazing early is to allow you to quit early such that accumulation of biomass is not unduly reduced. At the two sites in the above-mentioned study in Tennessee, biomass production from the cessation of grazing in early June through fall dormancy was 3.9 and 4.9 tons per acre. These are still respectable yields. However, remaining on the switchgrass longer would have had a disproportionately greater impact on the amount of regrowth available for biomass production.

Depending on the value of the biomass and the value of beef, it may make sense to remain on the switchgrass longer or, conversely, forego grazing altogether. For example, assuming a modest biomass price of $60 per ton, beef prices would have to decline to $0.80 per pound before gross revenues would be greater for producing biomass only and foregoing grazing (Figure 20.3a). On the other hand, assuming a constant price for beef of $1.40 per pound, biomass would have to be worth $110 per ton to make it worth only producing biomass (Figure 20.3b). Because prices of beef have only rarely dropped as low as $0.80 per pound in recent years and most forecasts for biomass value are well below $110 per ton, it is reasonable to conclude that grazing in the spring, at least for the first 30 days of the season, will always be worthwhile.

An important consideration in evaluating the trade-offs between grazing and biomass production could be the nature of the biomass contract. In a spot market, there would be plenty of flexibility for the



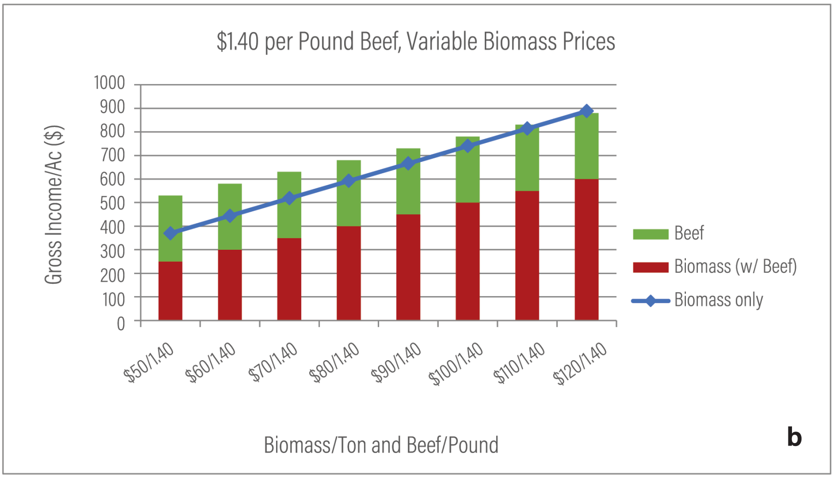




*Figure 20.3. When switchgrass being grown for biomass production is used for late spring pasture, grazing can boost revenue. Where assumed biomass price is $60 per ton, beef prices would have to be at or below $0.80 per pound before grazing would no longer provide increased revenue over biomass production alone (a). On the other hand, assuming a price of $1.40 per pound for beef, biomass prices would have to reach $110 per ton or more before grazing would reduce revenue versus biomass production alone (b). University of Tennessee, unpublished data.*

producer to decide how to balance these two options. But if the producer is operating under a contract that stipulates some number of tons be delivered annually, diverting some of the yield into forage may require a greater acreage of switchgrass be grown to enable such flexibility. This would apply to removal of forage for hay as well. Conversely, in situations where the biomass buyer limits or suspends switchgrass deliveries during a particular year, some or all of the switchgrass could be used for forage production.

*Harvesting biomass fields for hay*

Much of the foregoing applies to utilizing switchgrass for hay production as well. Harvests should be taken early to maximize forage nutritive value and to minimize loss of biomass production. Switchgrass harvested in late May in Tennessee at the early boot stage produced 3.5 tons per acre of good quality hay[37]. Delaying the initial harvest until late June when the grass was at the early seedhead stage produced 5.5 tons per acre, but of a much lower quality hay. In this case, the improved yield may not have off-set the reduced quality. In addition, the later hay harvest reduced biomass yield by 1.3 tons per acre compared to the one at boot stage. Other studies have indicated that the appropriate point at which to take the early hay harvest is prior to stem elongation[24; 51; 58]. Not only does this ensure high forage nutritive value, but it also maximizes subsequent regrowth. Harvests taken after stem elongation appear to weaken the plants and thus reduce subsequent yields. Where biomass is being produced under the terms of a contract, the reduced yields resulting from later hay harvests may be problematic.

Another consideration with the hay harvest scenario is that implementing an additional harvest comes at a cost due to doubling the number of trips across the field. An economic analysis that compared break-even prices for biomass bears this out with the single-cut system becoming profitable at $49 per ton while the two-cut system did not do so until $62 per ton[6].

*Other native grass options*

Other native grasses have been evaluated for their potential to produce biomass for energy, particularly big bluestem[36; 62]. Studies indicate that there is potential among these other species to be viable biomass crops. However, in studies in Tennessee and Illinois, neither big bluestem, indiangrass nor blends of these two produced as much tonnage as switchgrass. In the Illinois study, a lowland switchgrass produced nearly 50 percent more tonnage (6.3 versus 4.2 tons per acre) than either big bluestem or indiangrass[34]. Furthermore, any blend in that study that included switchgrass yielded more than those that did not include it, a result identical to that from the Tennessee study[37].

Regardless of actual yield, mixtures may be an issue depending on the end use of the material. Therefore, it is important to identify the end user for the biomass and what their constraints are when considering use of polycultures. For example, where processing involves enzymes for digestion of cellulose to produce ethanol, mixtures may reduce the efficiency of the process. Because of this, processors of biomass intended for ethanol production may not be willing to purchase feedstocks comprised of multi-species blends. This also may be a concern with inclusion of other tall-growing warm-season forbs or legumes that could have senesced material still present in the feedstock at the time of a dormant-season harvest. On the other hand, cool-season legumes with shorter growth habits and/or that would no longer be present in the canopy following summer senescence could be an option in native grass stands intended for biomass or dual-use production. However, given the difficulty of establishing such species in native grasses, particularly stands being managed for biomass production with limited canopy disturbance, and the limited amount of N provided by such marginal legume populations, interseeding may not be worthwhile (Chapter 18).

## SUMMARY

Switchgrass lends itself well to being a dual-use crop that produces both forage and biomass. A major key to doing so successfully, however, is removing forage early in the growing season when nutritive value is high. Grazing at this time can produce excellent gains and considerable amounts of beef during a short period. Similarly, high yields of very good quality hay can be produced with harvests of vegetative material, prior to stem elongation. Later use of switchgrass can depress biomass yields, perhaps to unacceptable levels. While grazing will, in almost all cases, increase revenues over biomass production alone, hay harvest actually increases break-even prices for biomass. Because of lower yield potential, other native grasses either alone or in blends with switchgrass produce less biomass and do not appear to provide a clear advantage over switchgrass monocultures.

CHAPTER TWENTY-ONE

# Wildlife Conservation

Populations of grassland birds have declined precipitously over the past half century with no apparent relief in sight (see Chapter 3, Figures 3.13 and 3.14). Among 28 species of grassland birds that breed in the U.S., 17 have significant negative population trends over the past 50 years. Only three of these grassland species have such trends that are positive (www.mbr-pwrc.usgs.gov/cgi-bin/guild17.pl). Among nine species found in and around eastern pastures or hayfields, all show negative population trends over the past 50 years (Table 21.1). For several of these species, the trend is weak but for others, such as the northern bobwhite, it is quite pronounced. The bird conservation organization Partners in Flight has calculated "half-life scores" for declining species. The half-life is the number of years until the population is reduced by one-half based on current trends. For the bobwhite, this figure is only 10 years. This situation has led 25 state fish and wildlife agencies and a number of their partners to form the National Bobwhite Conservation Initiative to develop range-wide strategies to address this problem (www.bringbackbobwhites.org/conservation/nbci-2.0/). Furthermore, for most of these species, the declines are occurring across much of their breeding range; it is not an isolated pattern. In the case of the northern bobwhite, there is virtually no part of their range east of the Great Plains where declines are not severe (Figure 21.1).

It is also worth noting that the declines for the species in Table 21.1 are evident irrespective of migratory status. Put another way, regardless of anything that may be occurring on wintering grounds outside the U.S., these species are still being impacted by conditions on the breeding grounds within the eastern U.S. Given that these trends are not restricted to just a few species — virtually all grassland associated species appear to be affected — and that the declines have been persistent for a half-century, there is a sense of urgency to address the problem.

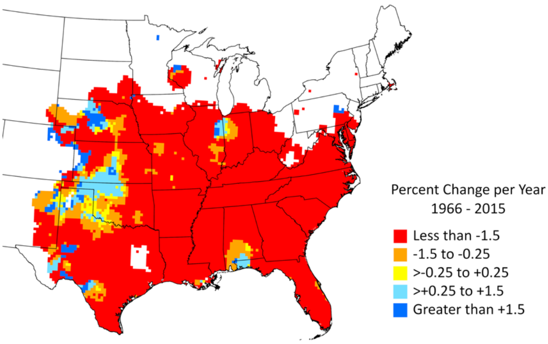



*Figure 21.1. Northern bobwhite populations across the eastern U.S. are declining with only rare exceptions. Red shaded areas indicate portion of northern bobwhite range where populations are declining (www.mbr-pwrc.usgs.gov/bbs/ra2015/ra2015_red_v3.shtml).*

*Table 21.1. Bird species commonly found in association with pastures and haylands of the eastern U.S. Note that all these species are experiencing some degree of population decline over the past half-century.*

| Species | Annual average decline (1966-2017) | Population lost since 1966 (%) | PIF half-life (years) | PIF Conservation Status | Migration |
|---|---|---|---|---|---|
| Northern bobwhite | -3.64 | 83.7 | 10 | Continental Importance | Non-migratory |
| Eastern meadowlark | -3.40 | 81.6 | 23 | Continental Importance | Short distance |
| Grasshopper sparrow | -3.31 | 80.8 | more than 50 | Continental Importance | Neotropical |
| Henslow's sparrow | -2.46 | 70.6 | more than 50 | Continental Concern | Short distance |
| Field sparrow | -2.46 | 70.5 | 36 | Continental Importance | Short distance |
| Prairie warbler | -2.12 | 65.1 | more than 50 | Continental Concern | Neotropical |
| Eastern kingbird | -1.42 | 50.3 | more than 50 | None | Neotropical |
| Common yellowthroat | -1.01 | 39.2 | more than 50 | None | Neotropical |
| Indigo bunting | -0.91 | 36.1 | more than 50 | None | Neotropical |
| Dickcissel | -0.53 | 22.8 | na | None | Neotropical |

## WHY THE DECLINES?

The cause of these declines has long been considered large-scale changes in the quantity and quality of grasslands that these species depend on for nesting and rearing their young. As discussed in Chapter 2, native grasslands, the habitat to which these birds are adapted, have largely disappeared.

*Lost woodlands and savannahs*

The extensive woodlands and savannahs of the eastern U.S. (Figure 21.2) with their well-developed herbaceous ground layers, scattered shrubs, sometimes in dense thickets, and a range of overstory canopy conditions provided ideal habitat for many of the species listed in Table 21.1, notably northern bobwhite and field sparrow[25]. Of course, the species in that table considered grassland obligates, such as eastern meadowlark and grasshopper sparrow, would have been more common where

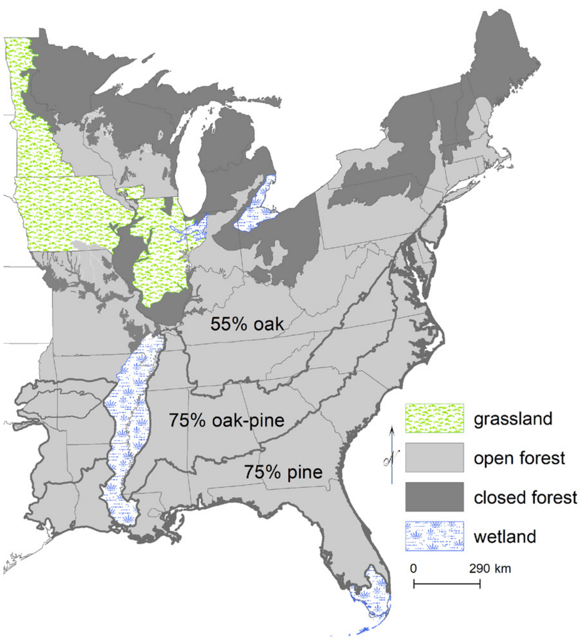



*Figure 21.2. Woodlands and savannahs were once prevalent across the eastern U.S. but have been almost completely eliminated. Although there would have been numerous areas of closed-canopy forests throughout, many scientists believe that the matrix, the dominant cover, was some form of more open canopies as depicted on this map. These open forests have been converted to row crop agriculture or closed-canopy forests, among other uses. Source, Hanberry and Thompson, 2019.*

woodlands and savannahs gave way to more open landscapes where trees were sparse. With the conversion to other uses, virtually all of the habitat provided by woodlands and savannahs has been lost. Within the Midwest, from Minnesota to Missouri and east to Michigan and Ohio, there were once more than 27 million acres of oak-dominated woodlands of which less than 1 percent are still present today[42]. This does not include the tens of millions of acres of oak or oak-pine woodlands that once occurred to the south of those states in places such as Kentucky, Tennessee and the Carolinas. If anything, there are even fewer acres remaining of such plant communities in these states. A similar fate has befallen the once extensive (more than 100 million acres) longleaf pine savannahs of the southeastern U.S. Not surprisingly, an assessment of conservation needs for various ecosystems of the U.S. identified savannahs as the most imperiled[41].

*Lost native prairie*

As has been the case with woodlands and savannahs, the more open grassland communities of the eastern U.S. have also been converted to other land uses, overwhelmingly to row crop production. One example is the Big Barrens which straddles the border in western Kentucky and Tennessee. This three million-acre prairie, once dominated by species such as big bluestem and home to a thriving population of prairie chickens, is now covered by row crops interspersed with scattered woodlots. The pattern is the same for other large eastern grassland regions including the Prairie Peninsula which stretched from Illinois into central Ohio, the Black Belt Prairie of eastern Mississippi and western and central Alabama, and the grasslands that once dominated much of the Great Valley of the Appalachians from Pennsylvania to Alabama. Indeed, it has been estimated that less than 0.1 percent of Tallgrass Prairie remains where soils and topography were conducive to crop production, which captures much of the former grasslands in what is now the eastern Corn Belt[50].

*Conversion to introduced grasses*

Despite these losses, extensive grasslands remain in the eastern U.S. These include 35 million acres of tall fescue and that proportion of the 30 million acres of bermudagrass which lies east of the Great Plains, along with several million acres of smooth bromegrass and bahiagrass. However, these species all form sods and are typically managed at canopy heights of approximately 3-8 inches. In addition, these species are all aggressive competitors, an attribute that obviously contributes to their resilience in forage production but can also have the effect of limiting plant species diversity in the sward. This combination of short stature, dense sods, the associated lack of bare ground and low plant species diversity all contribute to generally poor habitat for grassland birds. Collectively, these factors create what biologists refer to as "structure." Thus, for much of the eastern U.S. the issue on some 60 million acres of introduced forages is the quality of this habitat structure.

To illustrate this, let's consider tall fescue and northern bobwhite. Studies have shown that in tall fescue stands the amount of bare ground, something critical for mobility of chicks as well as for adults for finding seed on the ground, is unacceptably low[4; 43]. Protein-rich insects critical to the rapid growth and development of hatchlings may be present but are likewise unavailable to foraging chicks because of the density of vegetation at the ground level. Keep in mind, a bobwhite chick is about the size of a bumble bee when it first hatches. It simply cannot move effectively through dense sods; rather it requires some amount of open ground in which to forage for the insects. And, as mentioned above, tall fescue sods have been shown to limit development of preferred seed-producing plants that provide important food resources for the birds[4; 43]. That these fields do not provide desirable cover or other critical habitat elements for northern bobwhite was borne out by a radio-telemetry study that showed these birds clearly avoided tall fescue-dominated pastures and hayfields (Figure 3.15). The native grass pastures, by contrast, had taller canopies, were bunch grasses that allowed greater movement by the birds, and had greater plant species diversity. In another telemetry study, brooding adults using areas immediately adjacent to tall fescue pastures never once were located within those pastures (Figure 21.3). Instead, they remained in areas with more open ground and overhead cover, cover that made the broods less vulnerable to predators.

Another study of grassland birds, this one focused on grasshopper and field sparrows, showed that both species avoided tall fescue fields in preference to native grass pastures when selecting nest sites[7]. Furthermore, grasshopper sparrow nest density was greater in native grass pastures than it was in tall fescue pastures. As a result, more young were fledged from native grass pastures than tall fescue pastures, up to six times more on a per acre basis. An important part of the reason for this greater preference for and production in native grass pastures was that canopies during summer remained about 18-20 inches tall. This is in sharp contrast to heights within tall fescue pastures, which were typically less than 8 inches tall, especially during the summer nesting and brood-rearing season (Figure 21.4). Such greater heights for the native grasses are consistent with recommendations for forage production (Chapter 10).

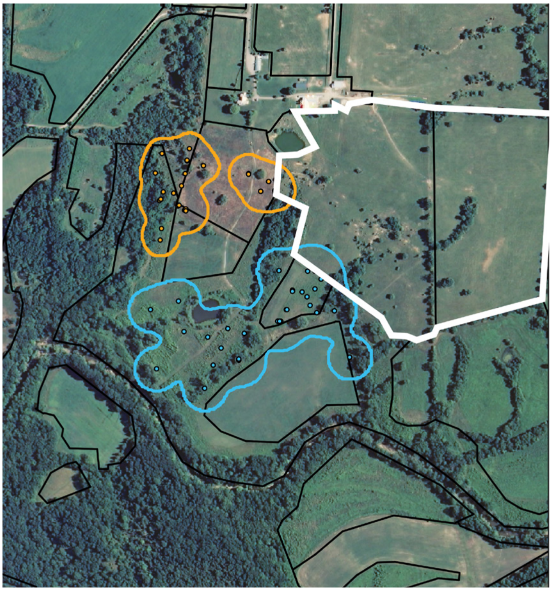


*Figure 21.3. Locations of two brooding adult bobwhite (orange and blue dots) and their associated brood ranges (orange and blue lines, respectively) during a radio-telemetry study in Kentucky. Note that no locations were recorded in the tall fescue-dominated pastures (white outline). A lack of cover and a dense sod that restricted chick mobility and foraging ability for insects kept them in the indicated home ranges. West et al., 2012.*

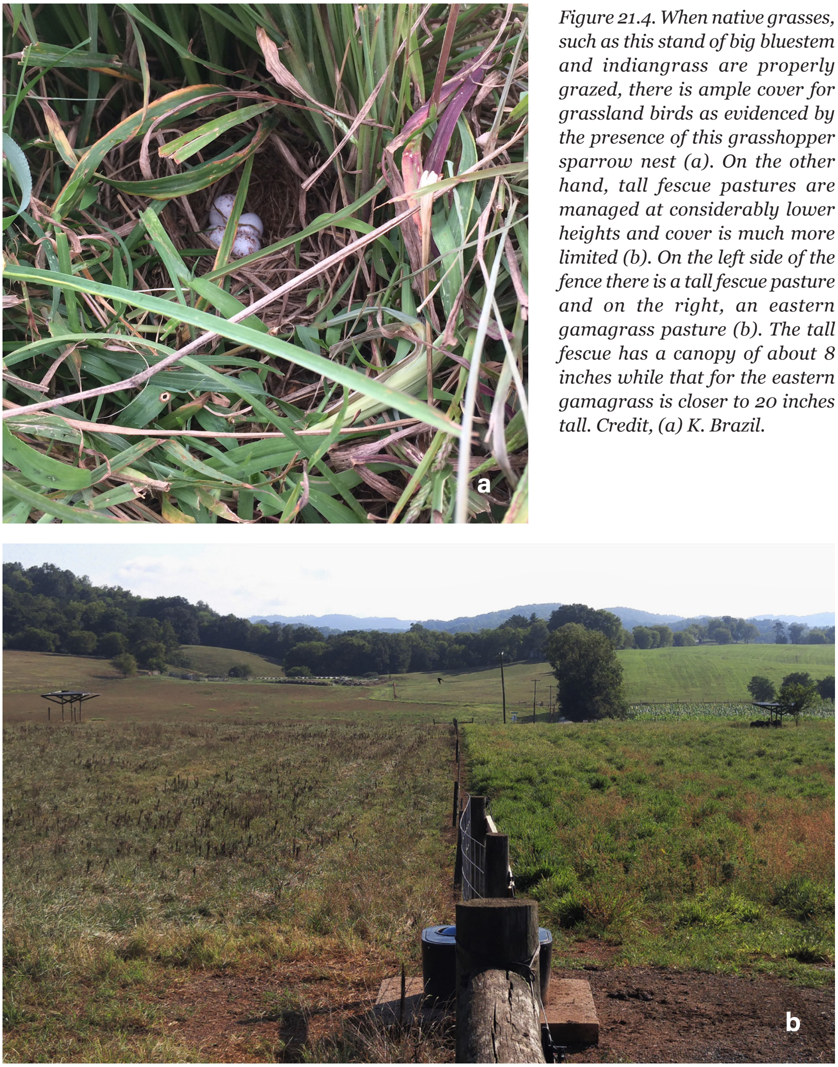



*Figure 21.4. When native grasses, such as this stand of big bluestem and indiangrass are properly grazed, there is ample cover for grassland birds as evidenced by the presence of this grasshopper sparrow nest (a). On the other hand, tall fescue pastures are managed at considerably lower heights and cover is much more limited (b). On the left side of the fence there is a tall fescue pasture and on the right, an eastern gamagrass pasture (b). The tall fescue has a canopy of about 8 inches while that for the eastern gamagrass is closer to 20 inches tall. Credit, (a) K. Brazil.*

*Landscape context*

Another factor that has, no doubt, impacted use of existing grasslands in the eastern U.S. is landscape context, that is, the kind of cover surrounding pastures and hayfields. As shrub areas have grown up, fencerows have been cleared, and adjacent forests are no longer burned and/or their canopies have closed, the field itself becomes less usable to the birds (Figure 21.5). Several studies have shown that fields in heavily wooded areas, those not in largely open settings, are much less likely to be used by grassland birds than those surrounded by more extensive grasslands (Figure 21.6)[33; 60]. Bobwhite telemetry studies have consistently documented greater bird use of and survival rates within areas near brushy cover[8; 44].


*Figure 21.5. A good example of why many grassland-associated bird populations are declining is provided by this pair of aerial photographs of an agricultural landscape in southern Ohio. In 1950 (a), field sizes were small, hedgerows were abundant, hay and pasture were interspersed with row crop fields and small patches of brushy cover were plentiful. Sixty years later (b) field sizes had increased and many of the other habitat features had been eliminated as farming had become "clean." No doubt productivity of crops had increased, but the unintended consequence of these changing land use practices has been dramatic declines in grassland species. Courtesy Ohio DNR.*


*Figure 21.6. Cover surrounding pastures and hay fields influences the value of the habitat within the field. The "hard edge" surrounding this hay field (a), for example, provides no transition from the field and the closed-canopy forest itself is not beneficial for quail. By contrast, the thick tangle of blackberry vines on the right and the shrubby fenceline at the back edge of this native grass pasture (b) provide cover that makes this field desirable habitat for species such as bobwhite, field sparrow and common yellowthroat.*

### *Importance of grazing and fire*

Another important consideration for grasslands, especially from the perspective of wildlife habitat, is disturbance. In the case of grasslands, disturbance refers to the two main factors that keep grasslands grasslands, grazing and fire. Indeed, a grassland is more than simply a collection of grasses and associated plants. These disturbances are an integral part of what makes this collection of plants a healthy, functioning community, a grassland. And what we are learning about these disturbances, and the structure that they create, is that they are every bit as important to grasslands wildlife as they are to the grassland itself. This is particularly true of the more humid environment in the eastern U.S. where severe drought plays less of a role in keeping grasslands from succeeding into forests. For example, early explorers traveling through the southeastern Coastal Plain, where annual rainfall averages 50-60 inches, reported that Native Americans burned the pine savannahs nearly annually. In a recent oak woodland restoration project, biennial fires over a period of many years appeared to be needed to successfully suppress well-established woody midstories and stump sprouts[56].

One problem in areas with ample rainfall (above 35 inches per year) is that perennial grasses can be quite dominant where fire is the only disturbance. In a Tennessee study during which native grass stands were burned annually for five years, tall species maintained site dominance, often over 80 percent cover, and forbs remained a minor stand component, 5-10 percent cover[27]. This same pattern has been reported from long-term burning studies conducted in the Kansas Flint Hills[12; 55]. In the absence of grazing, therefore, such stands can become quite rank and habitat structure beneficial to many grassland birds does not develop[26]. Thus, the other major natural disturbance within North American grasslands, grazing, may be essential for producing the appropriate structure needed by grassland birds, perhaps more so for northern bobwhite than some of the other species.

In recent years many range scientists have pointed out that the combination of fire and grazing is the most natural and, therefore, appropriate approach to managing grasslands of the U.S.[21; 22]. This approach is the underlying concept behind patch-burn grazing systems (see Chapter 10) and marries fire with the selective grazing patterns of cattle to produce a high degree of structural variability within pastures. Studies have shown that wildlife benefit from the structure and within-pasture variability that patch-burn grazing creates. For example, under patch-burn grazing a given pasture may simultaneously have patches that are recently burned and heavily grazed, more lightly grazed with an abundance of forbs and patches with heavier grass cover resulting from limited grazing. This provides habitat for species adapted to each condition as well as for species that use all three conditions within the same season [11; 28] (Figure 21.7). It should not be a surprise that North American grasslands wildlife are adapted to the range of natural disturbance patterns of North American grasslands [13; 23].

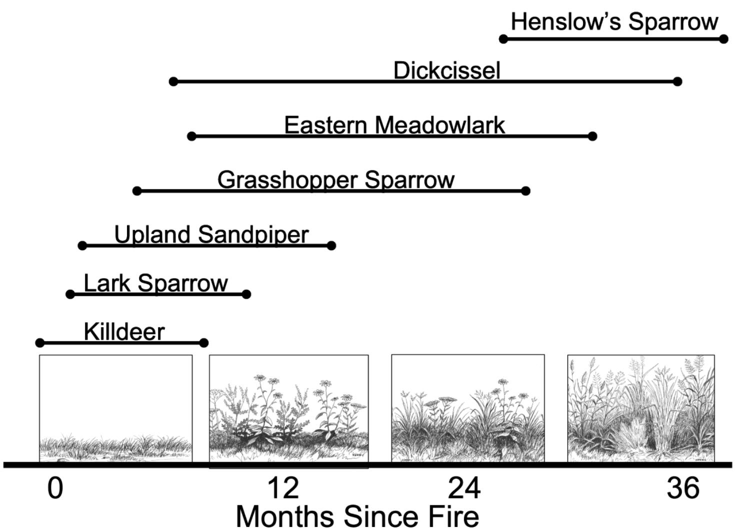



*Figure 21.7. Grassland birds are adapted to varying degrees of disturbance as depicted in this graphic. Some birds prefer grasslands more recently burned and, consequently, exposed to heavier grazing and the resulting short vegetation. Others prefer heavier vegetation and, therefore, less frequent fire and lower grazing intensity. There are also species, such as depicted by the dickcissel, that need a range of habitat conditions from lightly to heavily disturbed. Source, Fuhlendorf et al., 2009. Conservation Biology 23:588-598.*

## CATTLE PRODUCTION — THE SOLUTION?

Based on the information presented above, how can we most effectively improve habitat for at-risk grassland birds? One traditional solution has been to set aside land specifically for wildlife conservation. A good example of this approach is the USDA's Conservation Reserve Program (CRP).

Under CRP, nearly 35 million acres were taken out of production and planted to cover to reduce soil erosion, improve water quality and, in many cases, improve wildlife habitat. However, this program is expensive (about $2 billion per year) and, over the typical 10-year contract for implementing CRP practices on a farm, each acre may only be disturbed once under program guidelines. While fire can be used for such disturbance, it is not common and grazing is almost never used. Therefore, in the eastern U.S., grassland habitat quality declines a great deal during the life of the contract.

An alternative is to rely on a "working lands" conservation approach. Under this conservation model, no ground is taken out of production. Instead, management is adjusted to accommodate other objectives, such as wildlife[32; 33]. What adjustments can be made in forage production in the eastern U.S. to benefit wildlife? One consideration is to change grazing practices in existing pastures to those that favor increased canopy height, bare ground and plant diversity. However, the forages that currently dominate eastern grazing lands are naturally low growing and form sods. Increased plant diversity in pasture settings (unlike on native range) usually comes in the form of problematic weeds rather than native forbs. Regardless, the sods in well managed pastures tend to restrict development of broadleaf species. Use of fire with the common introduced forage grasses can be a good practice and has many of the same benefits with them as it does with native grasses. However, it normally only thickens sods and thus will not improve wildlife habitat. As it turns out, the best habitat for bobwhite in introduced-grass pastures occurs where the site is poor and sods remain thin, where there is brushy encroachment that keeps sods partially open — as well as providing overhead cover — or where abusive grazing has been practiced (Figure 21.8). Whether from a conservation or forage production standpoint, poor grazing practices are never recommended.

A much more effective strategy is to plant pastures and hayfields to native grasses. These species, because of their taller growth habit, greater canopy heights under grazing management, and bunch form,

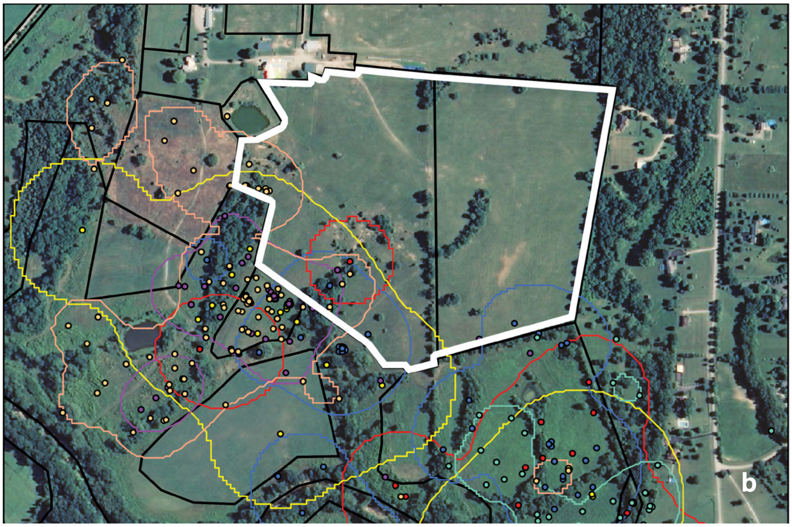




*Figure 21.8. This pasture, once dominated by tall fescue, has been grazed year-round with no management and, as a result, has become a weedy mess (a). It has also become useable habitat for bobwhite as demonstrated during a radio-telemetry study that found a pair using this area for several weeks during summer. Even though this is providing habitat for bobwhite, it is not good pasture management. Telemetered quail in another study (colored dots) only rarely were located in the two adjacent, well managed tall fescue pastures (b, top center, white outline). In fact, use of these pastures was almost entirely confined to spots where woody thickets had developed in drains at the edge of the tall fescue pasture on the left. Credit, (a) D. Mitchell and (b) West et al., 2012.*

can provide very good habitat for grassland birds while still being grazed[32; 33; 39; 61]. Really, without grazing, the quality of the habitat they provide is actually diminished for many species of wildlife[26]. A recent radio-telemetry study in Missouri found that bobwhite avoided ungrazed native grass pastures, selected for those that were

***But aren't predators the real issue?***

Many people wonder if rather than habitat, predators are the real issue underlying the declines in species such as bobwhite. To be fair, with the collapse of fur markets and the almost complete cessation of trapping of predators including bobcat, fox, coyote and raccoons, the populations of these "varmints" have increased. Furthermore, with the protection of hawks and owls and with the ban on use of DDT, raptor populations are also up in recent decades. Could these increased populations of predators be the real culprit? There are two answers to that question. First, it is true that predators can suppress populations of bobwhite, especially where habitat quality is poor. However, the other half of this answer is that where habitat quality is good, where structure is appropriate, northern bobwhite continue to thrive. There are many examples of properties throughout the Southeast where habitat improvements have been made and bobwhite have responded strongly, increasing 5- or as much as 10-fold. In most of these cases, there has been absolutely no changes in predator numbers. Only the habitat has been changed.

grazed and had greater nest success rates in those grazed native grass pastures. Thus, these grasses offer a very straightforward opportunity for improved forage production and wildlife conservation on the same acres. To capture this conservation benefit, virtually no modifications to normal grazing practices are required.

Continuous grazing, rotational grazing, or patch-burn grazing can all produce desirable habitat in native grass pastures. Regardless of the grazing strategy, the real key is maintaining appropriate canopy heights and moderate stocking densities. In a study conducted in Tennessee, fewer grasshopper and field sparrow fledglings were produced per acre when native grass pasture canopies remained at about 14 inches versus

18 inches during the nesting season[7]. Where canopies are maintained below the forage production levels recommended in Table 10.2, habitat quality will also be diminished.

Stocking densities required to maintain canopies at a height appropriate for grassland birds will vary based on site productivity and the quality of the stand of grass. With continuous grazing, stocking densities will almost never be so high as to result in excessive nest trampling. However, with rotational grazing, stocking densities are typically much higher and nest trampling may be more common. At extremely high stocking densities, such as would occur under either management-intensive or mob grazing, virtually all nests within a paddock would be destroyed. In situations with excessive stocking densities, successful nests will only be produced during rest periods when a particular paddock is unstocked.

*Hay production*

Hay production is inherently less friendly to grassland wildlife than grazing. As mentioned above, not only is grazing a natural part of grasslands ecology, but the wildlife native to these grasslands is adapted to thrive in the presence of grazing. With haying, however, all vegetation is removed to a height of about 3 inches with introduced forages and to 8 inches with native grasses. In either case, this removes cover essential for nests and broods and, in most cases, the equipment traffic itself destroys nests present at the time of harvest. The problem is further compounded by the timing of hay harvests, at least for cool-season grasses. Normal harvest timing for these grasses falls directly in the middle of nesting season effectively eliminating all nests within the field being harvested.

In an effort to avoid all of these impacts, biologists have often made the recommendation to delay hay harvests until after nesting is complete, typically July or August. Given the strong negative impact this has on the quality of the hay crop, it is not a very practical solution. Because of the naturally later harvest dates for warm-season native grasses, there is an opportunity to reduce nest loss during hay production. For eastern gamagrass and switchgrass, harvest dates for hay are typically only about three weeks later than those for cool-season forages. For big bluestem and indiangrass though, normal harvest dates are not until mid- to late June in the Mid-South. The additional time that this provides can substantially improve the likelihood of a successful nesting attempt (Figure 21.9). Common introduced warm-season perennials such as bahiagrass or bermudagrass also have later haying dates but their shorter growth habits provide less nesting cover prior to and following the initial hay harvest.

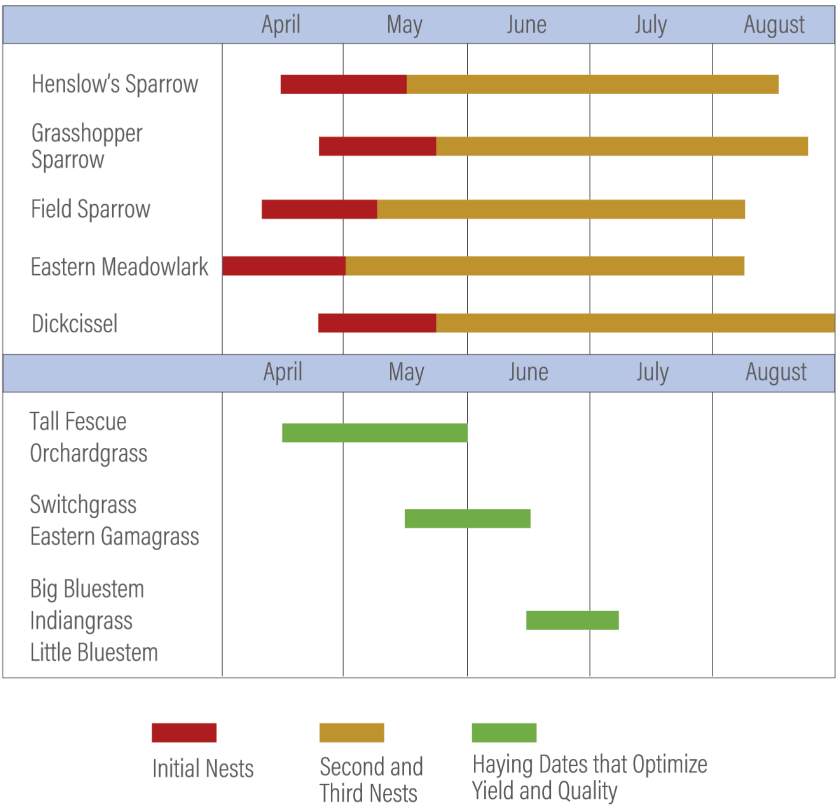



*Figure 21.9. Relationship between nesting and hay harvest timing for grassland birds in the Southeast. Note that the timing of initial nesting attempts and hay harvest always overlap except for the big bluestem blend. With introduced forages, harvest heights are such that all nests will be destroyed during cutting. Native grasses by contrast, allow for later harvest dates that provide a more favorable window for birds to complete a nesting cycle. Adapted from SP731H, Figure 3.*

***Agriculture as the solution?***

In recent years, discussions about "sustainable" agriculture have become more common. Concerns have been raised about impacts of contemporary agricultural practices on soil health, water quality, climate and biodiversity. These are all legitimate concerns that deserve to be addressed. However, as our society becomes increasingly urbanized it has also become more removed from agriculture and, consequently, much less familiar with it. As this knowledge gap widens, there is greater room for misunderstanding and, unfortunately, misinformation. In an effort to help close this gap and address concerns about the sustainability of agriculture, groups such as the U.S. Roundtable for Sustainable Beef (www.usrsb.org) have been formed. In terms of sustainability, persistent declines in grassland-dependent wildlife and pollinators are real issues that should concern us all. The opportunity that a working lands conservation approach provides is a perfect platform to showcase the benefits of sustainable agriculture. Better still, it is an opportunity to show that agriculture is not the problem but rather, that agriculture can be the solution. Under such a working lands model, forage production based on native grasses can actually be the tool that demonstrates that sound agricultural production practices can be used to address seemingly intractable conservation challenges.

## POLLINATOR DECLINES

In a trend not very different than that described above for grassland birds, pollinators have also experienced steep population declines in recent years. This includes managed hives of honey bees, native bumble bees and a host of other native bees and butterflies that are less well known. For instance, numbers for managed hives have dropped by nearly 60 percent since 1950. Given the importance of pollinators to the food we eat — 75 percent of crop species depend on insect pollinators — this is a serious concern. Why have these populations dropped so much? The quick answer is that we do not know with any certainty. With managed hives, colony collapse disorder has been a factor over the past two decades. Other likely problems relate to “clean farming,” environments where we have become very effective at reducing weed populations. Unfortunately, many of the weeds we control can also be important host plants for pollinators. A good and very well-known example is with monarch butterflies and milkweed. Unfortunately, milkweed is not welcome in the pastures of most cattle producers because of toxicity issues.

Although the precise cause of pollinator declines may not be known, one prospective strategy for improving their plight is to take proactive steps to improve the supply of host plants, nectar sources critical to these species’ survival. There are several options with native grasslands for such improvements. And recall, as described in Chapter 18, the grasslands of the eastern U.S historically included literally hundreds of species of forbs and legumes, most of which provided pollinators with nectar. While these grasslands are largely gone, converted to other uses, there are opportunities to incorporate various forbs and legumes into forage production systems that rely on native grasses.

There are three basic approaches that can be taken to improve pollinator habitat in native grass forages. First, one or more small areas, perhaps one quarter acre up to 2 acres each can be set aside where mixes of various flowering plants beneficial to pollinators can be established. Not only can such patches provide a much needed boost to these at-risk species, they are also very aesthetic. Although habitat improvements at this modest scale would not work well for the grassland birds, which need large areas, such patches can still prove quite useful for pollinators. There are programs administered by USDA’s Natural Resources Conservation Service that provide cost-share and technical assistance for establishing such pollinator plantings.

The other two approaches, which both fall into the category of working lands conservation as described above, involve enhancing existing pastures and hayfields. The first approach, interseeding legumes into native grass stands, is addressed in Chapter 18. Introduced species such as red and ladino clover can, with proper management, work in native grass pastures and at the same time provide feeding sources for many pollinators, including honey bees. As discussed in Chapter 18 though, studies to date do not show a strong yield or quality response with these cool-season species when interseeded into native grasses. However, if the value of improved pollinator habitat is taken into account, the net benefit will be greater.

The second working lands option is to interseed native forbs or legumes into native grass pastures. The species listed in Table 18.1 could be expected to provide some benefit to various native bees and/or butterflies (Figure 21.10). The key to providing that benefit though, will be their ability to persist — and flower — under grazing. Research currently underway at the University of Tennessee is attempting to assess how well those species can accomplish these goals (Figure 21.11). And, as is the case with maintaining appropriate conditions for birds, extreme grazing pressure,

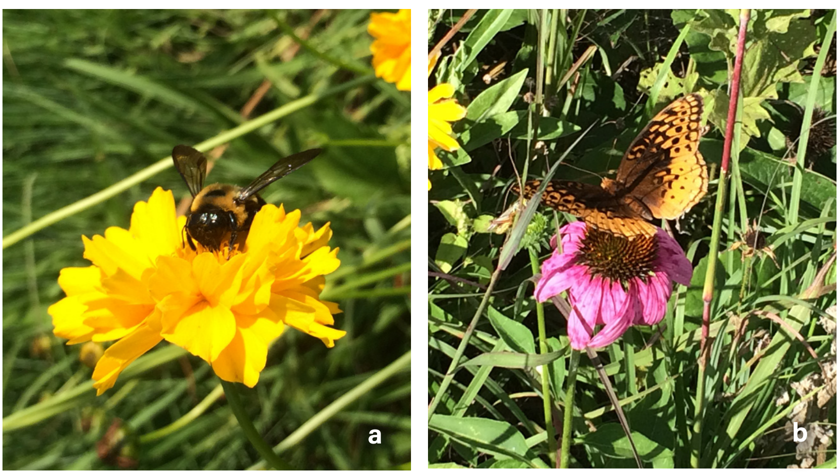



*Figure 21.10. Pollinators take advantage of native forbs, in these cases, lanceleaf coreopsis (a) and purple coneflower (b) within native grass pastures. A working lands conservation approach may be an opportunity for benefiting declining pollinator species. Credit, J. Richwine.*


*Figure 21.11. An experimental native grass pasture that has been interseeded with a mix of native forbs and legumes. Note that the forbs are persisting in the pasture and are able to produce flowers important for pollinator feeding (a). Even under heavy grazing, some flowers can still be produced as is the case with this mid-August purple coneflower bloom (b).*

pressure that reduces canopies so much that the forbs and legumes are unable to flower, will preclude any benefit. Rotational grazing, if timed appropriately to allow rest periods long enough to enable the native forbs to flower, could prove very useful in enhancing pollinator habitat in pastures.

One final option is to be judicious in your weed control program. In Chapter 15 the concept of thresholds for weed control was mentioned.

Managing weeds is never an issue of eliminating all weeds from a pasture or hayfield. Rather, it is about finding a balance between the cost and benefit of implementing control measures. Depending on the weed species in your pasture, it may be that those plants providing benefit to pollinators could be allowed a higher threshold before control is implemented. This could allow for more flowers and more pollinator feeding. To minimize the potential for the infestation to worsen, the plants could be clipped after flowering but still in time to preclude successful seed set.

## SUMMARY

With the almost complete loss of native grasslands in the eastern U.S., populations of wildlife adapted to these grasslands have also declined precipitously. Although more than 60 million acres of grasslands remain in the region, they are dominated by introduced species. These species are not bunch or tall grasses and are managed at shorter canopy heights than native grass forages. The sods they form often restrict plant diversity thus limiting important food sources for wildlife. Cover surrounding pastures and hayfields has also become less favorable to many species of grassland-associated wildlife. Although setting aside some acreage for wildlife can be beneficial, a working lands approach where all acres contribute to both forage production and conservation is far more preferable. Because they are tall bunch grasses managed at greater canopy heights, native grasses provide an excellent opportunity for successful working lands conservation. Normal best grazing practices actually improve the value of native grasses for wildlife while providing good summer forage production. Later hay harvest dates also create more opportunity for successful nesting prior to cutting. Similarly, declining pollinator populations could also benefit from a working lands approach based on native grasses. Inclusion of introduced legumes or native forbs and legumes in native grass pastures may provide improved habitat for at-risk pollinators.

## CHAPTER TWENTY-TWO
# Soil Health

In recent years, there has been an increased interest in soil health. What do native grasses have to do with soil health? Do they reduce it, improve it or have little effect on the health of soils? A related subject is how these grasses may impact soil carbon pools. Do they sequester carbon and, thus, reduce the amount of carbon in the atmosphere? More importantly, do native grasses do so at a higher rate than other crops and grasses? This chapter provides a brief overview of how soil health and carbon sequestration are influenced by native grasses.

### WHAT IS "SOIL HEALTH?"

If we are going to understand the relationship between soil health and native grasses, we first need to be sure we understand what is meant by "soil health." The best place to start this discussion is to recognize that there is a difference between soil and dirt. Dirt is simply the inorganic components of soil — silt, clay and sand. Soil, on the other hand, is dirt plus organic matter along with the complex web of life that this organic matter supports. The organic matter in soils is largely made up of carbon, one of the basic building blocks of life. Carbon occurs in many forms in soils but can simply be divided into that which is in living tissue and everything else. Within living organisms, carbon is found in bacteria, fungi and micro- as well as macro-invertebrates. But the vast majority of this carbon, 98-99 percent by mass, occurs in the roots of living plants. Despite the small proportion of mass made up of microorganisms, their numbers within grassland soils are mind boggling[46]. In the case of bacteria, estimates place the numbers at 10 million per

*Figure 22.1. Nematode populations number into the millions per acre and include taxa that are herbivores, fungivores, microbivores and even predators. Together, they form an important part of the complex biological web that contributes to healthy soils. Credit, J. Eisenback.*

ounce of soil. For fungi, they may be more like one million for that same soil mass. The number of invertebrates is much lower at about 250,000 per square foot within the top 8 inches of soil for nematodes (Figure 22.1). Earthworms may be more like 30 per square foot within the top 12 inches of soil. Clearly, soil is very much a living thing!

Roots not only provide the major source of organic matter in soils, they also directly support the other life forms in the soil. This includes organisms that breakdown dead plant tissue (e.g., shredders and detritivores) and those that rely on living tissue (e.g., herbivores, mycorrhizae). Roots release compounds that create symbiotic relationships with a host of free-living and associative bacteria. Like the fungal mycorrhizae, these organisms are attracted to these root exudates, which are often in the form of carbohydrates that provide much needed energy to the bacteria. In return, the bacteria make another critical nutrient, nitrogen, available to the plants. Root exudates play another important role in soil health by contributing to improved soil aggregation. Taken all together, roots are the foundation of the vast and complex biology that makes dirt soil; they are the key to soil health.

*How is soil health measured?*

There are three general categories that together help define healthy soils — physical, chemical and biological. Among the physical measures, aggregation and bulk density are perhaps most important. Greater aggregation allows for greater stability in soils and lower bulk density leaves more room for pores critical to providing oxygen to the billions of microorganisms within the soil. Greater porosity also allows for greater water infiltration and storage. Chemical properties are those that we have long been familiar with and include soil pH, major macronutrients (N, P and K) and a number of micronutrients such as copper, zinc and sulfur that are also important to plant nutrition. Traditionally, soil science focused on these physical and chemical properties of soil, both of which are important. In more recent years though, the biological components of soil have received increased attention. This is by far the most complex — and least understood — component of soil health. What we do know, of course, is that greater soil organic matter levels are a sign of healthier soils. Closely related to abundant organic matter is soil respiration, a measure of the amount of metabolic activity of soil microbes[18]. While the diversity of these organisms is no doubt important, the number of species and the great variability in the composition of these communities makes it difficult to draw strict conclusions about soil health based on shifts in the abundance among the numerous taxa.

Based on the foregoing then, a healthy soil is one with good aggregation, low bulk density, good levels of fertility, high levels of organic matter and good soil respiration. Traditional soil samples can be used to assess the chemical properties. Soil organic matter can also be determined from these same samples by most soil test labs. The other factors are more difficult and time consuming to measure. However, given the foundational role that soil organic matter plays in soil health, it has often been used as a surrogate for soil health[16].

## NATIVE GRASSES AND SOIL HEALTH

As has been described in Chapters 1 and 3, native grasses produce large volumes of soil carbon through their extensive root systems. These roots also penetrate deep into soil providing channels through which water can infiltrate downward and nutrients can be brought upward from lower horizons (Figure 22.2). And of course, the deeper roots introduce

*Figure 22.2. This soil pit, dug in a Georgia red clay, a weathered soil known as an Ultisol, shows penetration of switchgrass roots to a depth of 8 feet. Soils from the southeastern U.S., such as that shown here, are highly weathered and typically have low levels of soil organic matter. The high volume of switchgrass roots provides an opportunity to increase those levels.*

organic matter deeper into the soil column. And, as just discussed, this organic matter is the foundation for the entire web of life within the soil, it feeds the soil microbial community as well as the much larger invertebrates. The quality of soils with long histories of dominance by grassland communities is legendary. In what is now the Corn Belt, soil development under grasslands has produced some of the most productive soils on Earth. It is important to keep in mind though, that in the warmer, more humid Southeast, weathering takes place more rapidly and consequently soil organic matter levels remain lower.

The large volumes of native grass roots also have important implications for water quality. Increased soil organic matter allows for greater water infiltration and retention capacity (Figure 3.12). With improved root development of any grass, but especially where there are native grasses with their high root volumes (i.e., organic matter), there will be improved soil moisture during dry spells. Studies have shown that soil microbial activity is greater where there is increased soil moisture. In contrast, dry soils have very limited respiration from these microbes[18]. And increased infiltration means less runoff, so less sediment leaving the field and entering waterways. Furthermore, nutrients, whether adsorbed to sediment or in solution, will be less likely to leave the field where there is greater infiltration. This improves soil fertility as well as reducing negative impacts to water quality associated with both sediment and excess N and P. The normally low fertilizer input requirements of native grasses also make it less likely to have high volume nutrient applications which are prone to off-site movement that degrades water quality.

As much as 95 percent of the organic matter inputs in grassland soils come not from litter on the soil surface but rather from the roots themselves[48]. This emphasizes how important good grass management is for developing healthy soils. Good canopy management (see Chapters 10 and 11) maintains strong root systems which, in turn, provide high carbon inputs, root exudates, soil aggregation, low bulk density and high biological activity. In fact, moderate grazing actually increases root development in native grasses[49; 53]. On the other hand, overgrazing that leaves weakened plants also leaves diminished root systems (Figure 10.1) and, in turn, compromised soil health (Figure 22.3). And as discussed in Chapter 3, the presence of native grasses as alternative summer forages provides increased rest for cool-season forages. This rest provides the opportunity to develop more vigorous root systems for that portion of the farm where cool-season species are being grown.

Incorporating warm-season species into a forage system provides other benefits to soil health beyond those directly attributable to improved root vigor. Healthy cool-season grass stands, those that are not overgrazed, have better developed canopies with greater leaf surface area. As a result, such stands are better able to protect the soil surface leading to less surface erosion due to rain impact, less runoff, and soils less likely to reach temperatures detrimental to healthy soil biota. In short, a healthy warm-season grass component can have a ripple effect resulting in healthier cool-season swards and ultimately, healthier soils across the farm.


*Figure 22.3. This heavily grazed pasture (a) shows all the signs of poor soil health: exposed mineral soil, limited litter cover and grass with very limited leaf surface area. It is safe to conclude that roots are diminished and, consequently, soil biological activity is low as well. By contrast, this native grass stand (b) has an abundant canopy and, no doubt, a large root volume supporting vigorous biological activity. Credit (a), J. Green.*

### *Perennials versus annuals*

The fact that native grasses are long-lived perennials provides another advantage in terms of soil health, at least compared to annuals. Many summer annuals are established with tillage. Besides increasing the possibility of erosion, tillage results in exposure of soil organic matter to more rapid degradation and, therefore, reduces overall carbon pools. Tillage also breaks down aggregation to the depth of the cultivation itself. It also increases compaction below the plow layer, at least where it occurs repeatedly through the years such as in situations where annuals are planted year after year. In addition, reliance on annuals ends up creating periods between annual crops, spring and/or fall, where there is little to no active root growth and limited presence of live roots. Perennials, even when they are dormant, are still alive and, consequently, maintain root respiration.

***What's soil health got to do with it?***

A recent study on the Piedmont Plateau provides a good example of why soil health matters. In this study, conducted on 37 farms across four states, N fertilizer was applied in late summer in support of stockpiling cool-season forage[20]. Yield responses were not what was expected – many sites showed absolutely no response to the applied N. As it turned out, the explanation for this limited response to N had to do with the level of biological activity of the soil. Soils that had high levels of microbial activity were those that already had organic N sources that supported vibrant microbial communities. In turn, these microbes transformed the N into a form that made it available to the grass. Therefore, because of the presence of the organic N, the addition of inorganic N had a limited impact on yield. In fact, N only increased yield cost-effectively on 24 of those 37 farms in the trial. The takeaway here is that good levels of organic matter, including organic forms of N can reduce or perhaps even preclude the need for fertilizer inputs – and that means more dollars in your pocket!

*Prescribed burning*

Prescribed burning removes virtually all above-ground organic matter. Although it may seem reasonable, therefore, to assume that repeated burning would lead to a reduction in soil carbon levels over time, long-term studies have not shown that pattern. Why not? Two reasons, really. First, so much of the carbon in grassland systems is below ground that burning is only able to impact a small portion — the most recent year's growth. Second, the burn stimulates grass growth enough that any loss is off-set by increased growth, which means more carbon is fixed through photosynthesis and stored back in root systems. In seven studies comparing frequently burned and unburned grasslands in the Midwest, those that were burned always had greater below ground biomass (i.e., carbon) than their unburned counterparts, on average 21 percent more[47].

Fire also reduces above ground pools of organic N — about 75 percent of it is burned up in the fire[48]. For this reason, there has been some resistance to burning because it is thought that over time, repeated burns will reduce N and, therefore, site productivity. While that may make sense at first glance, it apparently is not what actually occurs in North American grasslands. Long-term studies with annual burning in Tallgrass Prairies have not shown any reduction in either productivity or system N concentrations of burned sites, even after as many as 48

*Figure 22.4. A portion of this field (beyond man standing in field) was burned. The portion of the field that was not burned can be seen in the foreground. Note the surface litter in the unburned side and the more vigorous growth, darker green foliage and greater tiller density on the burned side. The vast majority of carbon and N in this field is below the soil surface and would not have been reduced by the fire.*

years of annual burning[5; 48]. A major reason for this lack of long-term impacts is that more than 97 percent of N in grasslands is stored below ground and protected from fire. However, fire does have numerous short-term effects on N-cycling that are influenced, in part, by increased growth rates of the C4 grasses (Figure 22.4) (also see Chapter 17). These include increased root mass, but with lower N concentrations, increased soil microbe metabolism of N, lower net mineralization rates of N and reduced denitrification. Put simply, despite some modest loss of N from burning litter, frequent fire does not lower overall N, rather it shifts where it is found within the system.

*Plant diversity*

It has been proposed that greater plant diversity will result in better soil health because different plants have different rooting depths, root structures and phenology. Although the principles behind these assertions are sound, and may often be true, greater plant diversity does not always produce greater belowground biomass[29]. What increased plant diversity has been shown to do though is increase the growth of fine roots and increase the proportion of plant growth allocated to roots versus above ground growth[54]. The reason fine root production is important is that fine roots turn over (are produced and then die) each year and are, therefore, the primary source of carbon entering the soil. So even if diversity does not increase total soil organic matter, it may improve carbon pools and cycling.

The other side of the diversity coin has to do with introduced species and how they impact native grasses. In a recent study, big bluestem and an introduced species, spiney plumeless thistle, were grown with and without N amendments and with and without grassland soil microbes. As it turns out, the N increased the competitive position of the introduced species (see Chapters 7 and 12) at the expense of big bluestem. On the other hand, the microbes in the native soil did not help the introduced species compete with big bluestem but rather made big bluestem more competitive[52]. Another interesting situation is with the toxic endophyte associated with tall fescue. Research has shown that this endophyte has an allelopathic effect on the germination of spores and colonization rates of mycorrhizae, reducing colonization rates by more than 70 percent[2]. Given the importance of mycorrhizae to native grasses, this could have a substantial competitive effect between tall fescue and native grasses. These studies drive home the point that native microbes play a very important role in keeping native plants competitive, especially where soil N-levels have become elevated.

## CARBON SEQUESTRATION

Soil organic matter is estimated to hold five to six times more carbon than the atmosphere and ten times that found in living organisms, both plant and animal[16]. Grasslands are one of the Earth's most effective ecosystems for carbon sequestration. For example, in the southeastern U.S., grasslands have an estimated 18 tons per acre of organic carbon within the upper 9 inches of soil[19]. By comparison, forests sequester 20 and crop land 12 tons of carbon per acre. Research focused on switchgrass as a bioenergy crop have documented high rates of carbon sequestration ranging from 3.4 tons per acre in a cool environment with short growing seasons (MN; within top 36 inches of soil[29]) to 6.2 tons per acre at an eastern Texas site (top 12 inches of soil[15]). In a study of switchgrass conducted at three sites in the southeastern U.S., 3.7 tons accumulated over the first five years of the stand and 5.1 tons after 10 years[38]. Clearly, C4 native grasses are capable of sequestering large amounts of carbon.

Management of these grasses will, of course, effect how much carbon is actually sequestered. As has been discussed for grazing management (Chapter 10), hay production (Chapter 11) and for wildlife and pollinator habitat (Chapter 21) as well as here regarding soil health, the key to sequestration is a vigorous root system which depends on a vigorous canopy. Persistent close grazing will not allow for strong root development and high rates of carbon storage. As might be expected, grazing results in greater soil organic matter accumulation than hay production (about 25 percent greater) because with hay production, a considerable amount of material is regularly removed from the field[17]. Fertilization that improves plant growth will also increase carbon storage belowground. Site also will influence sequestration rates with less productive sites producing less carbon.

Although there has been much discussion of developing carbon markets in recent years, progress towards development of these markets has been slow. Should this change, native grasses may provide cattle producers with the opportunity to develop a new source of income for their operations.

## SUMMARY

Maintaining healthy, productive soils is an important part of our stewardship. It also is an important part of maintaining—and even increasing—the productivity of our pastures and hay fields. While soil health is a complex issue, a major component of healthy soils will always come down to roots. Large volumes of healthy vigorous roots will contribute high volumes of organic matter and root exudates that together foster a healthy rhizosphere that supports a large, diverse soil biota. These same roots and their exudates promote good soil structure, reduce bulk density, increase porosity, enhance water infiltration and retention, reduce soil and nutrient loss, and retain valuable nutrients. All that from roots! And when it comes to producing such large volumes of roots, roots that grow deep, native grasses are an excellent tool.

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# APPENDIX A

## Native Grass Seed Sources

*Table A.1. Commercially available native grass cultivars and local ecotypes based on their region of origin. Selection of plant material for forage production should prioritize those from sources close to the planting site. Movement of cultivars/ecotypes from east to west/west to east is normally not an issue. Movement of plant material south of its origin normally results in reduced yields. Movement north can improve yields but if planted more than approximately 300 miles northward, winterkill becomes more likely. Figure A.1 indicates locations of regions referred to in this table. Note that for many of the cultivars and ecotypes listed in this table, origin and adaptation can readily overlap adjacent zones. Tables A.2 through A.8 provide additional information on each grass species as well as vendors who produce them (continued through page 419).*

| | Northeast | | Upper Midwest | |
|---|---|---|---|---|
| Big bluestem | Albany Pine Bush | east central NY | Bison | central ND |
| | Long Island | Long Island, NY | Bonanza | southeastern NE |
| | Niagra | western NY | Bonilla | east central SD |
| | | | Pawnee | southeastern NE |
| | | | Rountree | west central IA |
| Eastern gamagrass | | | | |
| | | | | |
| | | | | |
| | | | | |
| Indiangrass | Long Island | Long Island, NY | Holt | northeastern NE |
| | NY[4] | NY | Tomahawk | ND/SD |
| | PA ecotype | northwestern PA | Nebraska 54 | southeastern NE |
| | | | Scout | southeastern NE |

| | **Midwest** | | **Mid-South** | | **Deep South** | |
|---|---|---|---|---|---|---|
| | Crazy Horse | IN, throughout | KY Native | central KY | Earl | north central TX |
| | Kaw | northeastern KS | Mammoth | central KY | Supremeo | AR/TN/MS/AL/GA |
| | Prairie View | IN, throughout | MO ecotype | MO, throughout | | |
| | | | OZ-70 | Ozarks, southern IL | | |
| | | | Suther | central NC | | |
| | Kansas Native | southeastern KS | Highlander | western TN/western KY | | |
| | Missouri Native | central MO | Iuka | central and western OK | | |
| | Pete | KS/OK | KY Native | western KY | | |
| | PMK-24 | KS/OK | | | | |
| | Cheyenne | northwestern OK | Boone | central KY | Coastal Plains | eastern SC |
| | Iowa ecotype | south central IA | MO ecotype | MO, throughout | Excelso | AR/TN/MS/AL/GA |
| | MO ecotype | north central MO | Suther | central NC | GA Native | southwestern GA |
| | Osage | east central KS/OK | | | Lometa | central TX |

| | Northeast | | Upper Midwest | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| Little bluestem | Albany Pine Bush | east central NY | | | |
| | Ft. Indiantown Gap | southeastern PA | | | |
| | Long Island | Long Island, NY | | | |
| | | | | | |
| | | | | | |
| Switchgrass | | | | | |
| Lowland | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Upland | High Tide | MD | Forestburg | eastern SD | |
| | Long Island | Long Island, NY | Nebraska 28 | northeastern NE | |
| | NJ ecotype | NJ | | | |
| | Shelter | WV | | | |
| | | | | | |

| | Midwest | | Mid-South | | Deep South | |
|---|---|---|---|---|---|---|
| | Oto | southeastern NE/eastern KS | | | Southern Mix | AL/FL/GA/SC |
| | Rumsey | southern IL | | | | |
| | Aldous | northeastern KS | Cimarron | southwestern KS/OK/TX/NM | Coastal Plains | eastern TX/LA |
| | Blaze | NE/KS | KY Native | central KY | Gulf Coast | TX |
| | Camper | NE/KS | Ozark | southern MO/ southern IL | OK Select | Texas |
| | KS local ecotype | | MO ecotype | MO, throughout | | |
| | Prairie View | IN, throughout | | | | |
| | | | | | | |
| | Independence | east central OK | BoMaster | east central OK/AR | Alamo | southern TX |
| | Kanlow | east central OK | Colony | east central OK/AR | Espresso | AR/TN/MS/ AL/GA |
| | Liberty | east central OK/ southeastern NE | Grand Prairie | eastern AR, Grand Prairie | Tusca | southern TX |
| | | | Haymaker | northwestern NC | | |
| | | | Performer | east central OK/AR | | |
| | | | Timber | eastern NC | | |
| | Blackwell | north central OK, Osage Hills | Carthage | central NC | GA Native | southwestern GA |
| | Cave-in-rock | southern IL | Piney | eastern NC | Robusto | AR/TN/MS/ AL/GA |
| | MO ecotype | MO, throughout | | | | |
| | RC Chipewa | southern IL | | | | |
| | Shawnee | southern IL | | | | |

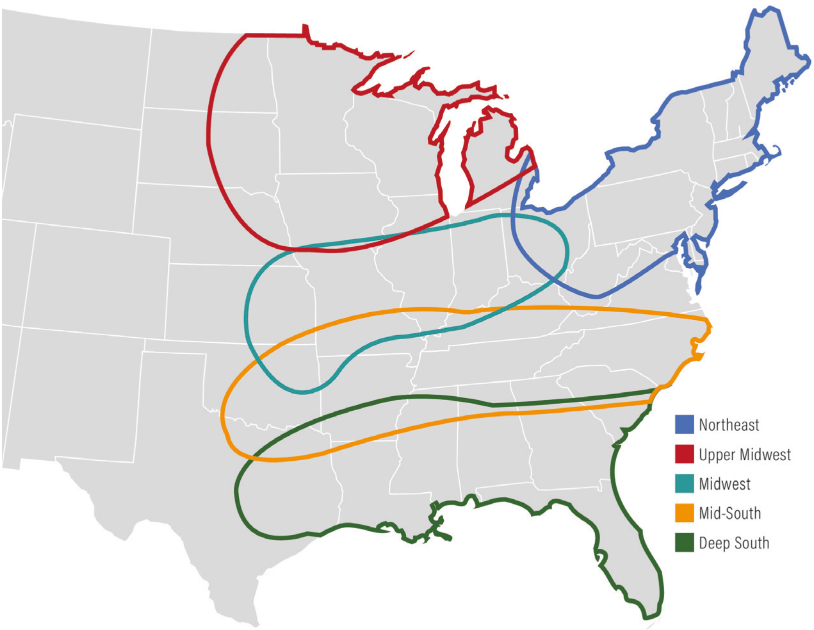



*Figure A.1. Broad geographic zones indicating sources of origin and approximate adaptation of native grass cultivars and ecotypes listed in Table A.1.*

*Table A.2. Seed producers for cultivars and local ecotypes listed in this appendix.*

| Vendor number | Vendor | Vendor website | Vendor phone |
|---|---|---|---|
| 1 | Bamert Seed | www.bamertseed.com | 800-262-9892 |
| 2 | Ernst Conservation Seed | www.ernstseed.com | 800-873-3321 |
| 3 | Gamagrass Seed Company | www.gamagrass.com | 800-367-2879 |
| 4 | Hamilton Native Outpost | www.hamiltonseed.com | 888-967-2190 |
| 5 | Johnston Seed Company | www.johnstonseed.com | 800-375-4613 |
| 6 | Osenbaugh's Prairie Seed Farm | www.prairieseedfarms.com | 800-582-2788 |
| 7 | Roundstone Native Seed | www.roundstoneseed.com | 888-531-2353 |
| 8 | Sharp Brothers Seed | www.sharpseed.com | 800-462-8483 |
| 9 | Star Seed, Inc. | www.gostarseed.com | 800-782-7311 |
| 10 | Stock Seed Farms | www.stockseed.com | 800-759-1520 |
| 11 | Turner Seed Company | www.turnerseed.com | 800-722-8616 |

*Table A.3. Commercially available cultivars and local ecotypes of big bluestem. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here.*

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| Albany Pine Bush | east central NY | 1985 | | 2 | local ecotype |
| Bison | central ND | 1989 | | 1 | |
| Bonanza | southeastern NE | 2004 | | 10 | improved selection from Pawnee |
| Bonilla | east central SD | 1991 | | 9 | |
| Crazy Horse | IN, throughout | 2022 | | 2 | selection from Prairie View for biomass |
| Earl | north central TX | 1996 | | 1, 11 | |
| Kaw | northeastern KS, Flinthills | 1950 | | 1, 4, 5, 7, 8, 9, 10, 11 | Goldmine is an improved cultivar based on Kaw |
| KY Native | central KY | 2000 | | 7 | local ecotype |
| Long Island | Long Island, NY | 2012 | | 2 | local ecotype |
| Mammoth | central KY | 2000 | | 7 | local ecotype |
| MO ecotype | MO, throughout | | | 4 | local ecotype |
| Niagra | western NY | 1986 | 165,000 | 1, 2 | |
| OZ-70 | Ozarks, southern IL | 2004 | 165,000 | 4 | |
| Pawnee | southeastern NE | 1963 | | 9, 10 | |
| Prairie View | IN, throughout | 2005 | | 2 | local ecotype |
| Rountree | east central IA | 1983 | 165,000 | 1, 4, 6, 10 | |
| Supremeo | AR/TN/MS/AL/GA | 2023 | | 7 | reduced seed dormancy, rapid germination |
| Suther | central NC | 2005 | | 2 | local ecotype |

*Table A.4. Commercially available cultivars and local ecotypes of eastern gamagrass. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here.*

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| Highlander | western TN/ western KY | 2003 | 2,800 | 7 | |
| Iuka | central and western OK | 1979 | 6,000 | 3 | |
| Kansas Native | southeastern KS | | | 9 | local ecotype |
| KY Native | western KY | 2003 | | 7 | local ecotype |
| Missouri Native | central MO | | | 9 | local ecotype |
| Pete | KS/OK | 1988 | 7,500 | 1, 3, 5 | note: 'Pete' is a new name for 'PMK24' |
| PMK-24 | KS/OK | 1974 | 7,500 | 4 | note: 'PMK24' was renamed 'Pete' |
| vns | | | | 8 | |

*Table A.5. Commercially available cultivars and local ecotypes of indiangrass. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here.*

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| Boone | central KY | 1994 | | 7 | local ecotype |
| Cheyenne | northwestern OK | 1945 | 175,000 | 1, 4, 5, 7, 8, 9 | |
| Coastal Plains | eastern SC | 2013 | | 7 | local ecotype |
| Excelso | AR/TN/MS/AL/GA | 2023 | | 7 | reduced seed dormancy, rapid germination |
| GA Native | southwestern GA | 2013 | | 7 | local ecotype |
| Holt | northeastern NE | 1960 | | 10 | |
| Iowa ecotype | south central IA | | | 6 | |
| Lometa | central TX | 1981 | 168,000 | 1, 11 | |
| Long Island | Long Island, NY | 2006 | | 2 | local ecotype |
| MO ecotype | north central MO | | | 6 | |
| MO ecotype | MO, throughout | | | 4 | local ecotype |
| Nebraska 54 | southeastern NE | | | 9, 10 | Scout is an improved cultivar based on NE54 |
| NY4 | NY | 2015 | | 2 | local ecotype |
| Osage | east central KS/OK | 1966 | 175,000 | 1, 4, 8, 9 | |
| Oto | southeastern NE/Eastern KS | 1970 | | 8 | Warrior is an improved cultivar based on Oto |
| PA ecotype | northwestern PA | 2004 | | 2 | local ecotype |
| Rumsey | southern IL | 1983 | | 1, 4 | |
| Scout | southeastern NE | | | 10 | improved selection from NE54 |
| Southern Mix | AL/FL/GA/SC | 2013 | | 7 | regional accession |
| Suther | central NC | 2005 | | 2 | local ecotype |
| Tomahawk | ND/SD | 1988 | | 9 | |

*Table A.6. Commercially available cultivars and local ecotypes of little bluestem. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here.*

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| Albany Pine Bush | east central NY | 2003 | | 2 | local ecotype |
| Aldous | northeastern KS, Flinthills | 1966 | 255,000 | 1, 4, 5, 7, 8, 9, 10, 11 | |
| Blaze | NE/KS | 1967 | | 8, 10 | |
| Camper | NE/KS | 1973 | | 9, 10 | |
| Cimarron | southwestern KS/OK/TX/NM | 1979 | 255,000 | 1, 5, 7, 8, 9, 11 | |
| Coastal Plains | eastern TX/LA | 2016 | 330,000 | 7 | |
| Ft. Indiantown Gap | southeastern PA | 2003 | | 2 | local ecotype |
| Gulf Coast | TX | | | 1 | local ecotype |
| KS local ecotype | | | | 8 | |
| KY Native | central KY | 1994 | | 7 | local ecotype |
| Long Island | Long Island, NY | 2012 | | 2 | local ecotype |
| MO ecotype | MO, throughout | | | 4 | local ecotype |
| OK Select | Texas | 2003 | | 1 | local ecotype |
| Ozark | southern MO/southern IL | 2010 | | 4 | |
| Prairie View | IN, throughout | 2005 | | 2 | local ecotype |

*Table A.7. Commercially available cultivars and local ecotypes of switchgrass. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here (continued on next page).*

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| **Lowland** | | | | | |
| Alamo | southern TX | 1978 | 427,000 | 1, 4, 5, 7, 9, 11 | |
| BoMaster | east central OK/ AR | 2006 | | 2 | bred from Kanlow and Pangburn, digestibility and yield |
| Colony | east central OK/ AR | 2010 | | 2 | bred from Kanlow and Pangburn, biomass |
| Espresso | AR/TN/MS/AL/ GA | 2023 | | 7 | reduced seed dormancy, rapid germination |
| Grand Prairie | east AR, Grand Prairie | 2015 | | 7 | local ecotype |
| Haymaker | northwestern NC | 2023 | | 2 | |
| Independence | east central OK | 2021 | | 2 | selection from Kanlow, biomass and winter hardiness |
| Kanlow | east central OK | 1963 | | 1, 4, 5, 7, 8 | |
| Liberty | east central OK/ southeastern NE | 2013 | | 2 | bred from Kanlow and Summer, biomass |
| Performer | east central OK/ AR | 2006 | | 2 | bred from Kanlow and Pangburn, digestibility and yield |
| Timber | eastern NC | 2009 | | 2 | developed for high biomass yield |
| Tusca | southern TX | 2023 | | 7 | imazapic resistant, based on Alamo |
| **Upland** | | | | | |
| Blackwell | north central OK, Osage Hills | 1944 | | 1, 2, 4, 5, 7, 8, 9, 10 | |
| Carthage | central NC | 2006 | | 2, 7 | local ecotype |
| Cave-in-rock | southern IL | 1974 | 259,000 | 1, 2, 4, 6, 7, 8, 9 | |

| Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|
| Forestburg | eastern SD | 1989 | | 7, 9 | |
| GA Native | southwestern GA | 2015 | | 7 | local ecotype |
| High Tide | MD | 2007 | | 2 | salt tolerant |
| Long Island | Long Island, NY | 2012 | | 2 | local ecotype |
| MO ecotype | MO, throughout | | | 4 | |
| Nebraska 28 | northeastern NE | 1949 | | 1, 7, 10 | |
| NJ ecotype | NJ | 2017 | | 2 | local ecotype |
| Piney | eastern NC | 2023 | | 2 | smaller plants, conservation |
| RC Chipewa | southern IL | | | 2 | selection from Cave in Rock for biomass |
| Robusto | AR/TN/MS/AL/GA | 2023 | | 7 | reduced seed dormancy, rapid germination |
| Shawnee | southern IL | 1995 | | 2 | selection from Cave in Rock, digestibility and yield |
| Shelter | WV | 1986 | | 2 | heavier stems, conservation cover |

*Table A.8. Commercially available cultivars and local ecotypes of wildryes. Availability based on native grass seed producers in the eastern U.S. Vendor number refers to the vendors in Table A.2. Many of the cultivars listed here can be purchased from other retailers in addition to those listed here.*

| Species | Variety | Origin | Release Year | Seed per Pound | Vendor | Notes |
|---|---|---|---|---|---|---|
| Canada | IA ecotype | IA/MO | | | 4 | local ecotype |
| | Lavaca | Southern TX | 2000 | 88,000 | 1 | |
| | vns | | | | 5, 8, 10, 11 | |
| Early | MO ecotype | MO | | | 4 | local ecotype |
| Riverbank | PA ecotype | Northwestern PA | 1994 | | 2 | local ecotype |
| Southeastern | Copiah | AR/TN/MS/ AL/GA | 2023 | | 7 | sun-tolerant landrace |
| | Maryland | MD/DE | 2012 | | 2 | local ecotype |
| | MO ecotype | MO | | | 4 | |
| Virginia | AR ecotype | Central AR | 2016 | | 2 | local ecotype |
| | Cuivre River | MO | 2002 | 73,000 | 4 | |
| | Jejunus | MO | | | 4 | |
| | Madison | NY/OH/NY/ PA | 2015 | | 2 | local ecotype |
| | PA ecotype | Northwestern PA | 1993 | | 2 | local ecotype |
| | vns | | | | 5, 10, 11 | |

# APPENDIX B
# Additional Resources

Many useful resources regarding native grass forages can be found in the references included within each section of this book. Some additional resources are listed below. Furthermore, state Extension services, seed dealers and the Natural Resources Conservation Service all provide helpful information.

## NATIVE GRASS COLLEGE

Three courses, each with multiple subsections, are available through the University of Tennessee Center for Native Grasslands Management. These courses, known as the Native Grass College, are listed below and available online at nativegrasses.tennessee.edu/native-grass-college/.

- Native Grass Establishment 101
- Competition Control 101
- Grazing Management 101

## PUBLICATIONS

### *Establishment*

Keyser, P., Hancock, D., Marks, L., Dillard, L. 2019. Establishing Native Grass Forages in the Southeast. PB 1873.

Keyser, P. D., C. A. Harper, G. E. Bates, J. C. Waller, and E. D. Doxon. 2011. Establishing native warm-season grasses for livestock forage in the mid-south. SP731-B.

Jennings, J., Simon, K., Mobley, M., Chaney, H., Hubbell, D. Native Warm-season Grasses for Forage. MP538.

Ownley, B., K. Goddard, S. Jackson, N. Rhodes, D.D. Tyler, and J. Walton. 2014. Guidebook for the Sustainable Production Practices of Switchgrass in the Southeastern US.

Surrency, D., Owsley, M., Kirkland, M. Seedling ID Guide for Native Grasses in the Southeast.

See also, Eastern Native Grass Symposium Proceedings (nativegrasses.tennessee.edu/articles/).

See also, articles at: Managing Native Grass Forages (nativegrasses.tennessee.edu/native-forages/).

### *Management*

Ashworth, A., P. D. Keyser, F. Allen, G. E. Bates, and C. A. Harper. 2012. Intercropping legumes with native warm-season grasses for livestock forage production in the Mid-South. SP731-G.

Bates, G., Beeler, J., Walton, J., Goddard, K. 2009 Adjusting and Calibrating a Drill for Planting Switchgrass for Biofuels. SP701-C.

Doxon, E. D., P. D. Keyser, G. E. Bates, J. C. Waller, and C. A. Harper. 2011. Economic implications of growing native warm-season grasses for forage in the Mid-south. SP731-E.

Keyser, P. D., C. A. Harper, G. E. Bates, J. C. Waller, and E. D. Doxon. 2011. Native warm-season grasses for Mid-south forage production. SP731-A.

Keyser, P. D., C. A. Harper, G. E. Bates, J. C. Waller, and E. D. Doxon. 2011. Establishing native warm-season grasses for livestock forage in the mid-south. SP731-B.

Keyser, P. D., G. E. Bates, J. C. Waller, C. A. Harper, and E. D. Doxon. 2011. Grazing native warm-season grasses in the Mid-south. SP731-C.

Keyser, P. D., G. E. Bates, J. C. Waller, C. A. Harper, and E. D. Doxon. 2011. Producing hay from native warm-season grasses in the Mid-south. SP731-D.

Keyser, P. D., C. A. Harper, and G. E. Bates. 2012. Competition control in native warm-season grasses grown for livestock forage in the Mid-South. SP731-F.

Keyser, P.D., C.A. Harper, G. Bates, R. Smith, T. Keene, C. Lituma. 2015. Using Prescribed Fire to Manage Native Grass Forages in the Mid-South. SP731-J.

Ownley, B., K. Goddard, S. Jackson, N. Rhodes, D.D. Tyler, and J. Walton. 2014. Guidebook for the Sustainable Production Practices of Switchgrass in the Southeastern US.

Walton, J., P.D. Keyser. 2015. Adjusting Mowing Equipment for Increased Stubble Heights When Harvesting Native Grasses. SP731-I.

See also, Eastern Native Grass Symposium Proceedings (nativegrasses.tennessee.edu/articles/).

See also, articles at: Managing Native Grass Forages (nativegrasses.tennessee.edu/native-forages/).

## *Conservation*

Ashworth, A. 2011. Native warm-season grass roles in water and soil conservation: a literature synthesis.

Brooke, J. and C. A. Harper. 2018. Renovating native warm-season grass stands for wildlife. PB 1856.

Burger, G. and P. D. Keyser. 2013. Ecology and management of oak woodlands and savannahs. PB-1812.

Burger, G. P. D. Keyser. 2013. The shelterwood-burn technique for regenerating oaks. PB-1813.

Harper, C. A, and G. E. Bates, M. P. Hansbrough, M. J. Gudlin, J. P. Gruchy, and P. D. Keyser. 2007. Native warm-season grasses: identification, establishment and management for wildlife and forage production in the Mid-South. PB-1752.

Harper, C. A., E. D. Holcomb, P. D. Keyser, J. L. Birckhead, J. C. Waller, and G. E. Bates. 2014. Wildlife considerations when haying or grazing native warm-season grasses. SP731-H.

Managing Oak Forests in the Eastern United States. 2016. Keyser, P.D., Fearer, T., and C.A. Harper, editors. CRC Press, Bacon Raton, FL. 305 pp. https://doi.org/10.1201/b19076.

Mitchell, D. and Keyser, P. 2020. Grazing and Fire: Critical Components of Grasslands of the Eastern United States.

See also, Eastern Native Grass Symposium Proceedings (nativegrasses.tennessee.edu/articles/).

See also, articles at: Managing Native Grass Forages (nativegrasses.tennessee.edu/native-forages/).

# APPENDIX C
## Native Grass Seedling Identification

Images for big bluestem (Figure C.1), eastern gamagrass (Figure C.2), indiangrass (Figure C.3), little bluestem (Figure C.4), and switchgrass (Figure C.5) seedlings are provided to aide in identification during early stages of development.



*Figure C.1. Newly emerged big bluestem seedling (a), seedling at the 2-leaf stage (third, smaller leaf is a remnant of the monocot or initial emergence and is not a true leaf) (b), 5-leaf stage (remnant leaf has died and fallen off) (c) but with no new tillers having yet developed. Note fine hairs along stem and those extending about one-third of the way up the base of the leaf. Even in seedlings, stems are somewhat flattened. Credits, J. Henning.*

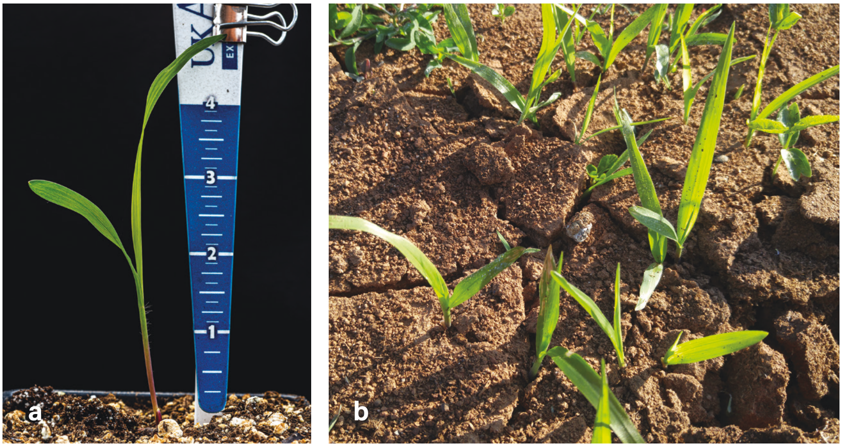
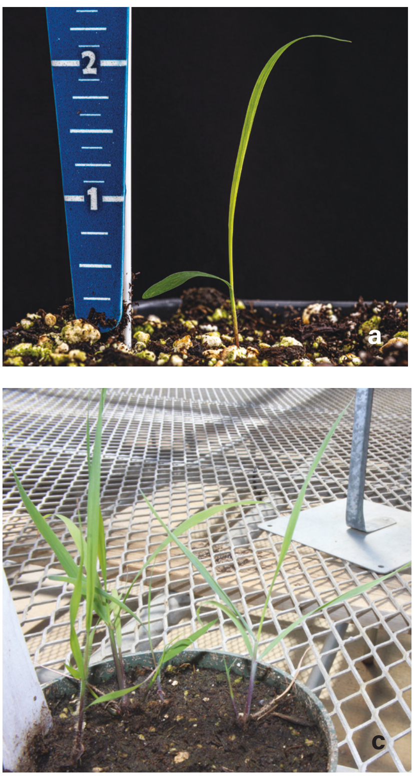



*Figure C.2. Newly emerged eastern gamagrass seedling (a) and a group of newly emerged seedlings with some beginning development of their second leaf (b). Note that leaves are broad and not hairy. Credit (a), J. Henning.*



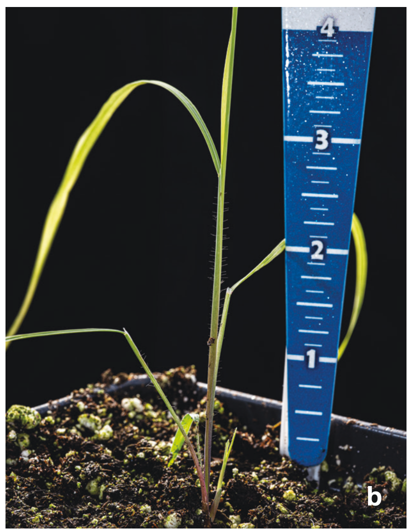




*Figure C.3. Newly emerged indiangrass seedling (a), a 5-leaf stage seedling beginning to develop a second tiller (lower right, at root crown) (b), and a group of seedlings at various stages of development (c) including tillered (seedling on back left and right), 4-leaf stage (front left), and 2-leaf stage (back center). Note reddish stems that are round in cross-section. Credits (a and b), J. Henning, and (c) L. Dillard.*

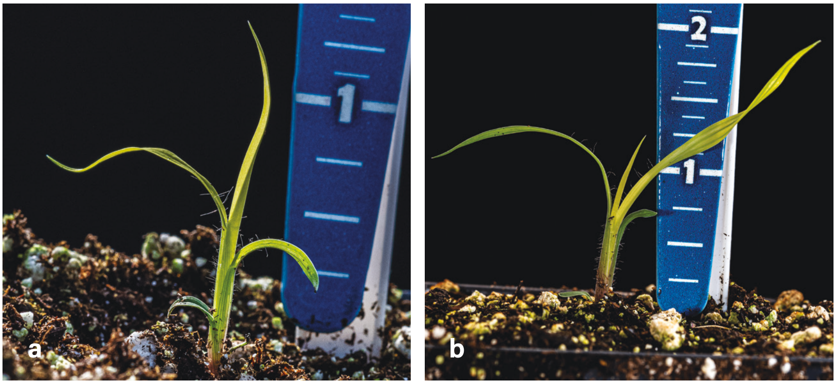



*Figure C.4. Little bluestem seedlings with nearly fully emerged third leaf (a) and third leaf just beginning to emerge (b). Note the fine hairs and the remnant monocot leaf in each case (lower left in a and lower right in b). Credits, J. Henning.*

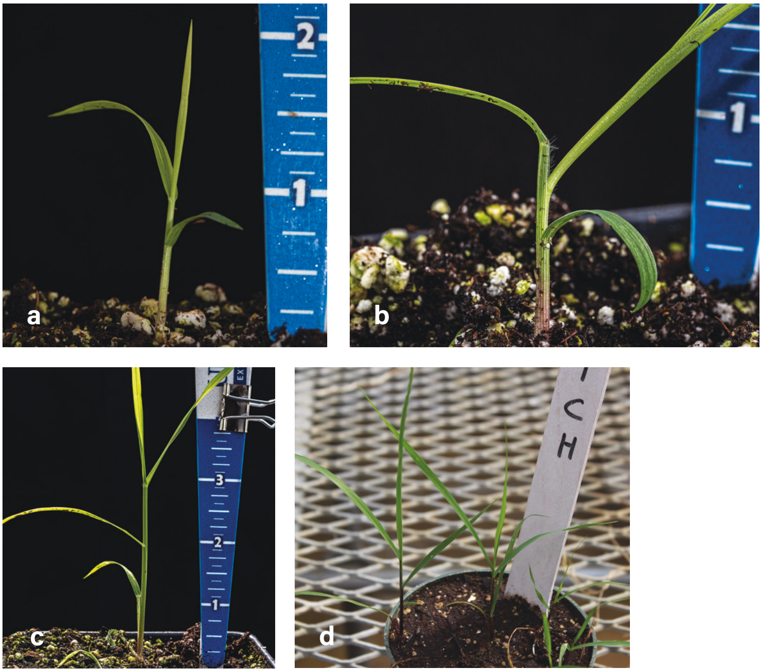



*Figure C.5. Switchgrass seedling developing its second true leaf (a), close-up of 2-leaf switchgrass seedling showing the fine hairs located at the base of the leaf (b), 4-leaf stage seedling (monocot leaf can be seen near the base of the plant on the left) (c), and a group of switchgrass seedlings at various stages of development (d) including two on the left that are developing their first tiller and two on the right that are at the 3-leaf stage. Note the red stems, which are round in cross-section and are without hairs. Credits (a, b, c), J. Henning, and (d) L. Dillard.*

# About the Author

Pat Keyser is a professor and director for the Center for Native Grasslands Management at the University of Tennessee. In that role, Professor Keyser provides regional and national leadership in the development and implementation of comprehensive research and outreach programs focused on the management of native grasslands. This includes work on use of native grasses in forage production systems for livestock, the integration of forage and biomass production, answering specific management questions for native grasses, restoration of natural grassland communities such as woodlands and savannahs, and wildlife responses to native grasslands management. He has authored or co-authored more than 60 grants worth nearly $11 million in support of his research (more than 60 research projects to date). This work has led to over 370 publications, including more than 90 articles in scientific journals. He has directed or co-directed 17 and mentored an additional 34 graduate students and made more than 400 presentations to a wide variety of audiences including students, scientists and producers. He and his wife of 39 years live in East Tennessee and have four grown children and five (really good-looking!) grandchildren.