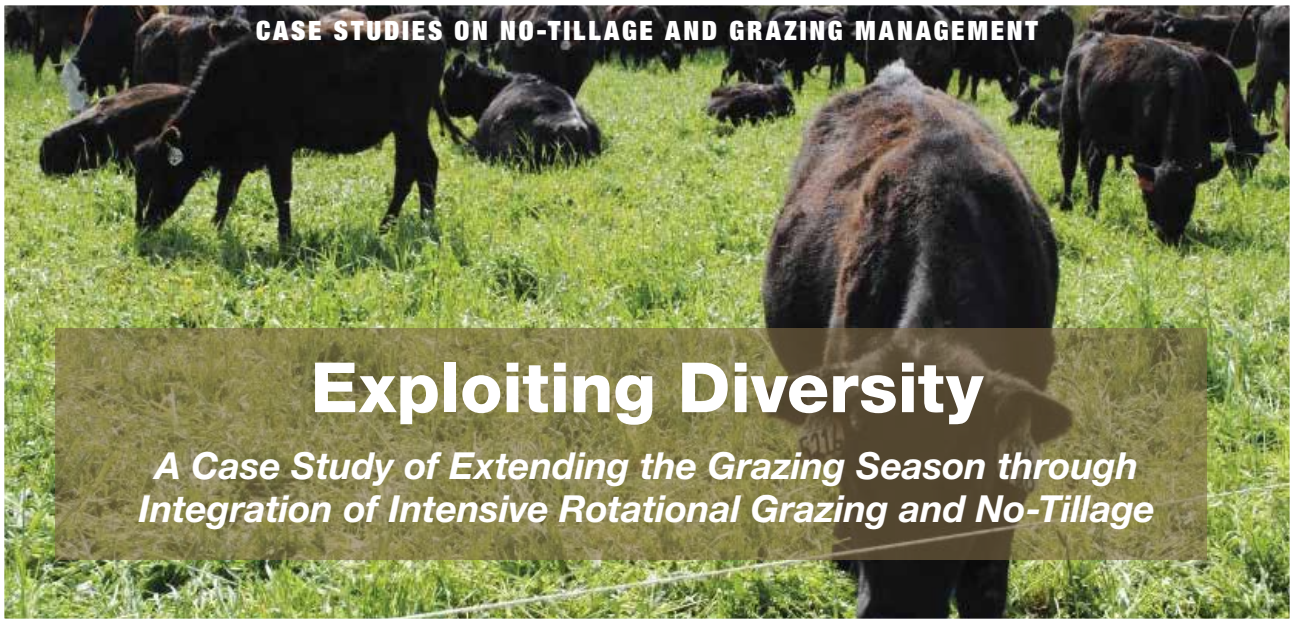
PennState Extension



CASE STUDIES ON NO-TILLAGE AND GRAZING MANAGEMENT

Exploiting Diversity

A Case Study of Extending the Grazing Season through Integration of Intensive Rotational Grazing and No-Tillage

Perennial pasture, if well managed, can be a highly sustainable form of land use (Figure 1). Soil erosion is kept to a minimum because the soil is permanently covered with living vegetation. Compared to annual cropping, surface soil organic matter and deep organic matter typically increase due to a vigorous root system, frequent root die-off upon defoliation followed by new root regrowth, and zero soil disturbance. Soil structure under permanent sod also improves due to a large, permanent root system. Most grazing operations in the Northeast rely on cool-season perennial forages such as orchardgrass, timothy, and red and white clover for their grazing animals. However, these cool-season perennials have some drawbacks (Figure 2). In the northeastern United States, their growth is reduced in the summer due to seasonally high temperatures and occasionally dry soil conditions. This causes grazing deficits on farms in the summer. Additionally, there is the long northeastern winter, which may cause pasture growth to be at a near standstill from November to March. In this case we will see how a farmer in northwestern Pennsylvania is using a multitude of annuals and perennials to expand his grazing season while managing for reduced inputs and improved soil health through integration of intensive rotational grazing and no-tillage.

Climate and Soils

Wilson Land & Cattle is the farm of Russ and Lennie Wilson in Tionesta, Pennsylvania. The farm is located in one of the coldest spots in Pennsylvania with annual extreme minimum temperatures ranging from -15 to -10°F (Figure 3). Mean annual precipitation is 43 inches, fairly evenly distributed throughout the year (Figure 4). The average monthly minimum temperature is lowest in January and February (14°F) and the average monthly maximum is highest in July (82°F). The major soil types on the farm are Wharton silt loam (moderately well drained), Cavode silt loam (somewhat poorly drained), Hartleton channery loam (well drained), Atkins silt loam (very poorly drained), and Armagh silt loam (poorly drained) (Figure 5). Slopes range from 0 to 15 percent. The main soil challenge faced on this farm is poor drainage—much of the farm is classified as somewhat poorly drained due to a seasonally high water table. This is caused by slow permeability. Other challenges are the high rock fragment content of the soils and steep slopes.

How It All Started

Russ and Lennie started farming here in 2009. The 130 acres of tillable land (besides 86 acres of forest) had been in crops but turned out to be visibly worn out and unproductive. After considering their options the Wilsons decided to convert their farm to a grazing farm with the expertise and assistance from USDA-NRCS. Soil samples were taken and sent to a laboratory for soil fertility analysis. Agricultural lime was applied to correct the pH. Six-strand high-tensile permanent fencing was installed in 2010 and 2011 to create 30 permanent paddocks (Figure 6). A water supply system was installed to bring water to all paddocks. Electric mobile fencing was purchased

to enable splitting up of the permanent paddocks. The Wilsons started rotational grazing in 2011. Because Russ observed positive effects on pasture productivity and soil health, grazing intensity was gradually increased over the years, and cows may now be moved multiple times a day. (Russ used to move his cows once every one or two weeks in 2012, but this increased to two to ten times a day in 2015.)

Animal Species

Today the Wilsons graze approximately 100 Angus cows (Figure 7), steers, and bulls; 30 Khatahdin cross sheep; and 40 Spanish and Savanna cross goats. Although they experimented with grazing hogs, chickens, and guinea fowl, they now concentrate on the cows, goats, and sheep. One reason for this is the effect of these different animals on the soil—the hogs tend to dig up the pasture and the chickens eat many beneficial soil insects that Russ cherishes. There is also the need to concentrate efforts to be successful instead of spreading oneself too thin. In most cases, the cows are grazed separately from the goats and sheep (Figure 8). One important reason for this is to avoid overgrazing by the goats and sheep. The typical routine for a paddock is to be grazed for a few hours by cows and then to be rested for at least one month. It would be easy to overgraze the pasture if the goats/sheep followed the cows, so that is not practiced frequently. Sheep and goats are more selective in their grazing practices, so it is also more difficult to maintain all desired species in the pasture. The other reason is that the goats and sheep are used intensively for invasive species control under trees in the forest and tree lines. Goats and sheep are typically moved less frequently than cows—once a day is a typical average.

Machinery

The Wilsons have made important changes to their farm that have allowed them to reduce expenses. One decision they made is to quit harvesting crops with machinery; they have sold all their harvesting equipment and rely completely on their cows, goats, and sheep to harvest all their crops. This does pose a challenge in this region because it has not yet been possible to graze 365 days a year. A major reason is that the pastures hardly grow from November to April. Another reason is that grazing when the soil is very wet is problematic. Sometimes the animals cannot be in the field without causing severe pugging and compaction. When Russ observes this, he will pull the animals from the land and put them in a covered shed with concrete flooring. He then feeds them hay, which he purchases from a local farmer. The manure produced by the animals while in the covered shed is collected, stored, and subsequently spread on the fields. By extending the grazing season, the time in the shed is limited to 70–80 days per year,

Figure 1. Well-managed perennial pasture can be a highly sustainable form of land use. SJOERD DUIKER

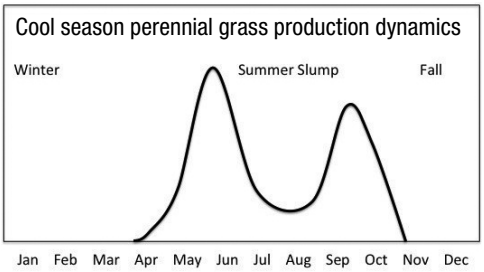


Figure 2. Cool-season perennial pasture production typically slows down in summer and stops in winter. SJOERD DUIKER

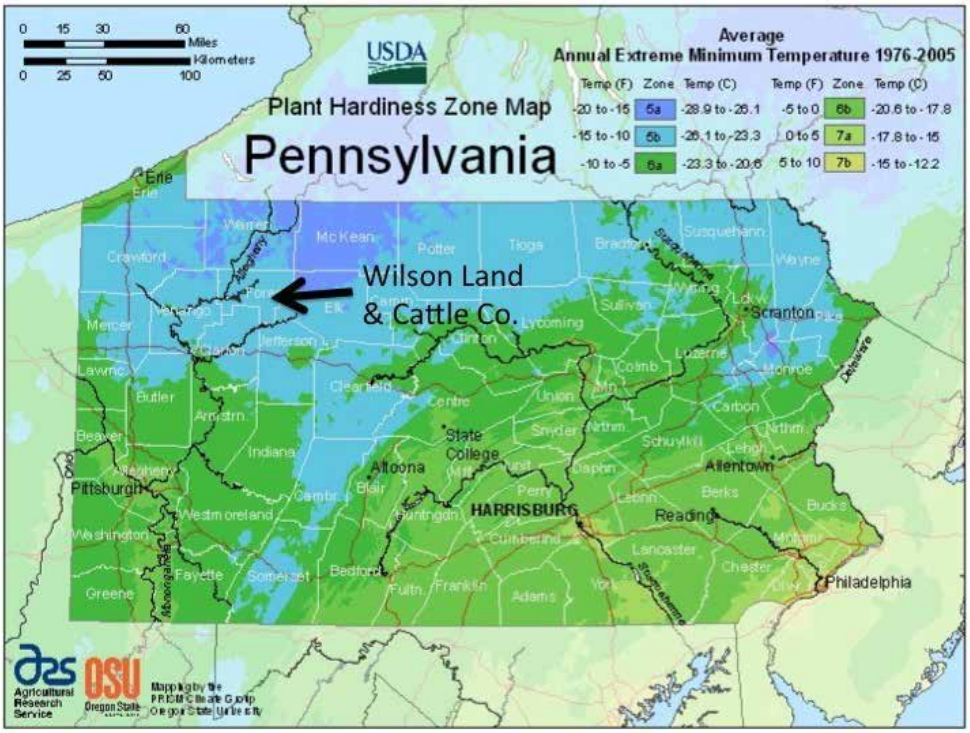


Figure 3. Location of the Wilson farm, one of the coldest areas in Pennsylvania.

so the amount of hay to feed and manure to spread has been reduced to a minimum (Figure 9).

Besides a manure spreader (Figure 10), this farm also uses a sprayer to apply herbicides (primarily for burndown prior to no-till establishment of a new forage stand), a no-till drill (Figure 11), a no-till planter, a 45-horsepower front-load tractor, a 60-horsepower tractor, and a lime spreader. Perhaps the most important piece of machinery is an ATV fully equipped with supplies to set and move mobile fencing (Figure 12). The ATV can run over a mobile fence without taking it down. The costs of diesel fuel have declined dramatically due to the reduction in machinery use. Annual diesel purchases declined from 3,500 gallons in 2012 to 200 gallons per year in 2016 and 2017.

Nutrient Management

One of the benefits of grazing is that most nutrients stay in the field. The removal of plant nutrients from a grazing farm in animal product is small compared with the plant nutrient removal in crops that are harvested and sold. The typical nutrient content of different types of hay is shown in Table 1. If a farmer harvests 3 tons of cool-season grass hay per acre, the removal is 135 pounds of nitrogen (N) per acre, 36 pounds of phosphate (P_2O_5) per acre, 150 pounds of potash (K_2O) per acre, 30 pounds of calcium (Ca) per acre, 12.5 pounds of magnesium (Mg) per acre, and 12.5 pounds of sulfur (S) per acre. If the Wilsons produced 3 tons of dry hay per acre per year on their 130 acres of cropland, they would remove 17,550 pounds of N, 4,680 pounds of P_2O_5, 19,500 pounds of K_2O, 3,900 pounds of Ca, 1,625 pounds of Mg, and 1,625 pounds of S (Table 2). Instead, the Wilsons only export nutrients from animals off the farm. Over the last 3 years, they sold on average per year 10 cows (1,150 pounds each), 2 freezer beef (1,000 pounds each), 6 steers/bulls (900 pounds each), 10 bred heifers (900 pounds each), 5 calves (450 pounds each), 20 calves (500 pounds each), and 60 sheep and goats (70 pounds each), for a total of 53 head of cattle, 60 head of sheep and goats, and a total production of 44,350 pounds per year. We used average nutrient contents of animals from the IFSM model of the USDA-ARS Pasture Lab (2.8 percent N, 0.72 percent P (phosphorus), 0.2 percent K (potassium), 0.15 percent S (data from personal communication with Al Rotz) to calculate the nutrients leaving the farm. At 44,350 pounds, that is 1,242 pounds of N, 319 pounds of P (731 pounds of P_2O_5), 89 pounds of K (106 pounds of K_2O), and 67 pounds of S. So the nutrient removal on this beef farm is only 7 percent of N, 16 percent of P, 0.5 percent of K, and 4 percent of S in a haymaking operation. The costs of the N fertilizer to replace removal of nutrients in hay on this farm would be 19.5 tons of urea (45 percent N) at $11,544, 5.2 tons of superphosphate (45 percent P_2O_5) at $701 per ton ($3,645), 16.25 tons of potassium chloride (KCl) (60 percent K_2O) for $9,669, or a

Figure 4. Wilson Land & Cattle in winter.

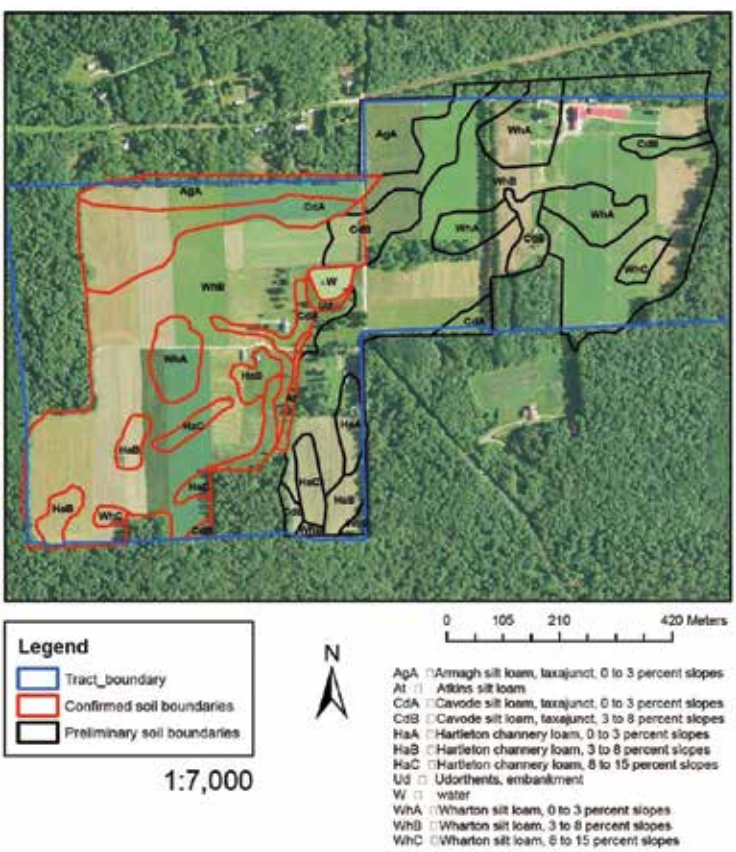


Figure 5. Soil map of the Wilson farm. COURTESY OF USDA-NRCS

Table 1. Typical nutrient contents of dry hay.

	N	P_2O_5	K_2O	Ca	Mg	S
	(pounds per ton)					
Alfalfa	60.0	15.0	60.0	28.0	5.0	5.0
Red Clover	56.0	12.5	45.0	14.0	6.0	5.0
Cool-Season Grass	45.0	12.0	50.0	10.0	4.5	4.5
Warm-Season Grass	35.0	10.0	35.0	10.0	5.0	3.5

Source: University of Missouri.

total of $24,858 per year. Besides not exporting many plant nutrients from the farm, hay purchases are also valued for the nutrients they contain. In an average year, Russ will buy about 60 tons of grass hay. With this hay he will import 2,700 pounds of N, 720 pounds of P_2O_5, 3,000 pounds of K_2O, 600 pounds of Ca, 270 pounds of Mg, and 270 pounds of S. The importation of nutrients in hay is therefore more than what is exported in animal product. The manure produced by the animals when they are in the covered shed is collected, stored, and then spread with a manure spreader when soil conditions are fit. Due to the farm balance of nutrients, the Wilsons have noted a reduction in need to purchase fertilizer. Fertilizer purchases have declined from more than $26,000 (2009) to $913 per year (2017).

Diversity in Plant Species to Meet Grazing Needs and Improve Soil Quality

The Wilson's goal is to meet the nutritional needs of their ruminant animals as much as possible through grazing—not in the least to avoid having to buy hay. They do this by growing 73 different plant species on their farm (Table 3). The species are always grown in purposefully designed mixtures. All plant species play a particular role. Generally speaking, the grasses are the high producers of energy and fiber. Grasses are also more persistent in the paddock than most broadleaves. Their feed quality depends on the stage of growth for grazing—the more mature they get, the less palatable they are for the livestock. The fibrous root systems of grasses are very important to build organic matter and strengthen soil structure. The grass root systems act as a "geotextile," making the soil resist the impact of the animal hooves. Legumes are added to the mixtures to supply protein and highly digestible forage to the animals. Another important reason for using legumes is to fix atmospheric nitrogen. This helps supply the nitrogen needs of not only the legumes themselves but also the companion grasses

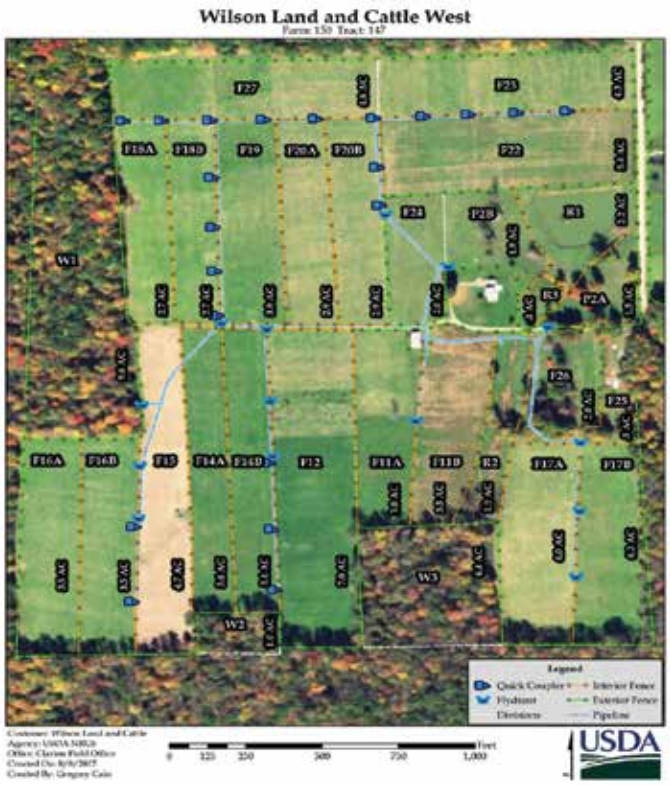


Figure 6. (At left and above) Farm layout showing exterior and interior permanent fencing and water system layout. COURTESY OF USDA-NRCS

and nonleguminous forbs. Another reason for using legumes is their root system. The root systems of many legumes are taprooted; they create large, continuous, deep pores in the soil and their large roots can break through compaction layers. Finally, nonleguminous forbs are also planted. These forbs are added to supply diversity to the animals' diet. Their root systems are also of interest; some species, like chicory or radishes, have taproots that create big pores in the soil (Figure 13). Chicory has been shown to increase organic matter content deep in the soil as well as the productivity of a grass pasture. The legumes and nonleguminous forbs are also added for their flowers because they attract pollinators and other insects.

Using Plant Diversity to Extend the Grazing Season

Fourteen species of cool-season perennial grasses, legumes, and nonlegumes are the mainstay of the grazing cow, goat, and sheep diet (see Table 3). These species are always grown in mixtures. Some species, like canarygrass, tall fescue, and red clover, are preferentially planted in soils that suffer from poor drainage due to their ability to withstand wet feet. Fescues and orchardgrass are planted because of their suitability for stockpiling. The cool-season perennials have a peak in production in the spring and another peak in the fall (Figure 14). They are supplemented with 11 species of cool-season annuals, 17 species of warm-season perennials, and 19 species of warm-season annuals to extend the grazing season. Growing annuals for a year can be a great method in a renovation program for perennial pastures (Figure 15). The Wilsons have found that planting new varieties of perennials can help improve pasture productivity,

Continued on page 8

Table 2. Comparison of hypothetical nutrient export if 3 tons of hay per acre per year were sold off the 130 acres of cropland from the Wilson farm compared with current average animal sales of 44,350 pounds and nutrient import in purchased hay.

	Hypothetical Hay Sales	Current Animal Sales	Nutrient Export in Animals from Hay Sale	Nutrient Import in Current Hay Purchases (60 tons per year)
	pounds per year		percent	pounds per year
N	17,550	1,242	7	2,700
P_2O_5	4,680	731	16	720
K_2O	19,500	106	0.5	3,000
S	1,625	67	4	270

Figure 7. Angus cows are the main species of animal on the Wilson farm. SJOERD DUIKER

Figure 8. Goats and sheep are typically grazed separately from the cows to avoid overgrazing and to use them for invasive species control. SJOERD DUIKER

Figure 9. The Wilsons have limited the amount of hay needed by extending the grazing season to almost 300 days per year. They buy approximately 60 tons of hay per year, which is also an important plant nutrient source for the farm. SJOERD DUIKER

Figure 10. A manure spreader is used to spread manure. The manure is collected when animals are fed hay in a covered shed during adverse soil conditions or lack of pasture. SJOERD DUIKER

Figure 11. A no-till drill is used to establish small-seeded annuals and perennials without any tillage. SJOERD DUIKER

Figure 12. The most important piece of equipment on the Wilson farm. SJOERD DUIKER

Table 3. Common and scientific name of plant species grown for forage on Wilson Land & Cattle farm in 2017. Note four classes of species—cool- and warm-season perennials and cool- and warm-season annuals. Within each class we recognize grasses, leguminous broadleaves, and nonleguminous broadleaves.

COOL-SEASON PERENNIAL GRASSES	WARM-SEASON PERENNIAL GRASSES
Orchardgrass (*Dactylis glomerata* L.)	Switchgrass (*Panicum virgatum* L.)
Timothy (*Phleum pratense* L.)	Big bluestem (*Andropogon gerardii* Vitman)
Perennial ryegrass (*Lolium perenne* L.)	Indiangrass (*Sorghastrum nutans* [L.] Nash)
Tall soft leaved fescue (*Lolium arundinacea* Schreb)	Coastal panicgrass (*Panicum amarum* Elliott var. *amarulum* [Hitchc. & Chase] P.G. Palmer)
Meadow fescue (*Schedonorus pratensis* [Huds.])	Eastern gamagrass (*Tripsacum dactyloides* (L.)
Red fescue (*Festuca rubra* L.)	
Chewings fescue (*Festuca rubra* L. ssp. *fallax* [Thuill.])	
Festulolium (meadow fescue × perennial ryegrass)	
Meadow brome (*Bromus biebersteinii* Roem. & Schult.)	
Smooth brome (*Bromus inermis* Leyss.)	
Canarygrass (*Phalaris arundinacea* L.)	
Bluegrass (*Poa annua* L.)	
Intermediate wheatgrass (*Thinopyrum intermedium*)	
Virginia wildrye (*Elymus virginicus* L.)	
COOL-SEASON PERENNIAL BROADLEAVES	**WARM-SEASON PERENNIAL BROADLEAVES**
Legumes	**Legumes**
Alfalfa (*Medicago sativa* L.)	Maryland senna (*Senna marilandica* L.)
Red clover (*Trifolium pratense* L.)	Showy ticktrefoil (*Desmodium canadense* L.)
White clover (*Trifolium repens* L.)	Panicledleaf ticktrefoil (*Desmodium paniculatum* L.)
Alsike clover (*Trifolium hybridum* L.)	Dillenius' ticktrefoil (*Desmodium glabellum* Michx.)
Yellow sweetclover (*Melilotus officinalis* [L.] Lam.)	
Strawberry clover (*Trifolium fragiferum* L.)	**Nonlegumes**
Birdsfoot trefoil (*Lotus unifoliolatus* [Hook.] Benth.)	Cup plant (*Silphium perfoliatum* L.)
Sainfoin (*Onobrychis viciifolia* Scop.)	Narrowleaf mountain mint (*Pycnanthemum tenuifolium* Schrad.)
Crownvetch (*Coronilla varia* L.)	New England aster (*Symphyotrichum novae-angliae* L.)
	Oxeye sunflower (*Heliopsis helianthoides*)
Nonlegumes	Wild bergamot (*Monarda fistulosa* L.)
Chicory (*Cicorium intybus* L.)	Virginia mountain mint (*Pycnanthemum virginianum* L.)
Small burnet (*Sanguisorba minor* Scop.)	Purple coneflower (*Echinacea purpurea* Moench)
Narrowleaf plantain (*Plantago lanceolata* L.)	Blazingstar (*Liatris aestivalis* G.L.Nesom & R. O'Kennon)
COOL-SEASON ANNUAL GRASSES	**WARM-SEASON ANNUAL GRASSES**
Cereal rye (C*ereale secale* L.)	Corn, open-pollinated and hybrid (*Zea mays* L.)
Annual ryegrass (*Lolium multiflorum*)	Milo (*Sorghum bicolor* L. Moench ssp. *Bicolor*)
Oats (*Avena sativa* L.)	Forage sorghum (*Sorghum bicolor* L. Moench)
Triticale (*Triticosecale rimpaui* C. Yen & J. L. Yang)	Sorghum-sudangrass (*Sorghum bicolor* L. Moench ssp. *Drummondii*)
	Teff (*Eragrostis tef* [Zuccagni] Trotter)
	Japanese millet (*Echinochloa esculenta* A. Braun)
	Pearl millet (*Pennisetum glaucum* L.)

Table 3, continued

COOL-SEASON ANNUAL BROADLEAVES	WARM-SEASON ANNUAL BROADLEAVES
Legumes	**Legumes**
Crimson clover (*Trifolium incarnatum* L.)	Soybean (*Glycine max* [L.] Merr.)
Hairy vetch (*Vicia villosa* Roth)	Cowpea (*Vigna unguiculata* [L.] Walp.)
Common vetch (*Vicia sativa* L.)	Lentil (*Lens culinaris* Medik.)
Deer pea vetch (*Vicia ludoviciana* Nutt.)	Sweet blue lupin (*Lupinus angustifolius*)
Partridge pea (*Chamaecrista fasciculata* [Michx.])	Trailing wild bean (*Strophostyles helvola*)
	Mungbean (*Vigna radiata* [L]. R. Wilczek)
Nonlegumes	Lablab (*Lablab purpureus* L. Adams.)
Radish (*Raphanus raphanistrum* subsp. *Sativus*)	Sunn hemp (*Crotalaria juncea* L.)
Turnip (*Brassica rapa* subsp. *Rapa*)	
	Nonlegumes
	Sunflower (*Helianthus annuus* L.)
	Buckwheat (*Fagopyrum esculentum*)
	Squash (*Cucurbita maxima* Duchesne)
	Plains coreopsis (*Coreopsis tinctoria*)

Figure 13. The root systems of grasses and forbs improve soil organic matter content and soil structure and make soil more resistant to compaction. COURTESY OF JIM RICHARDSON, SMALL WORLD GALLERY

Figure 14. This cool-season annual mix of hairy vetch, rye, annual ryegrass, crimson, and red and white clover can be grazed after the spring peak in production of cool-season perennials.

Figure 15. No-till-established annual forages can be a great way to renovate a perennial pasture without losing the soil health improvement realized under the perennial sod.

Figure 16. Summer annual mixture of Japanese millet, sorghum-sudangrass, forage sorghum, grain sorghum, annual ryegrass, teff, sunflower, mungbean, cowpea, white clover, and red clover being grazed in September. This gives cool-season perennials the opportunity to be rested for stockpiling. SJOERD DUIKER

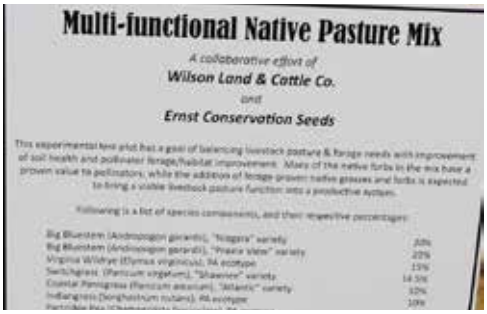


Figure 17. The Wilsons collaborate with Ernst Conservation Seeds in evaluating native species mixes for grazing. SJOERD DUIKER

so they tend to renovate their pastures from time to time. To get a clean start, it is beneficial to grow annuals for a year or two in that paddock to completely eradicate the old perennial sod. The annuals typically grow aggressively and compete fiercely with any remnants of the old sod that may try to regrow. At the same time, the annuals help supply grazing at a time when the perennial cool-season pastures are slowly growing, not growing, or need to be rested. For example, warm-season annuals can meet the grazing needs in the summer or early fall.

Summer annuals help alleviate the summer slump or allow perennial cool-season pastures to be rested from August to October so they can be grazed in the winter (Figure 16). This practice is called "stockpiling." Cool-season annuals have also found a place on the Wilson farm. They can be grown successfully after a perennial sod terminated in late summer or summer annuals. Annuals like rye can be grazed in the early spring before the cool-season perennials. Other cool-season annuals like hairy vetch can be grazed later (in June). Finally, warm-season perennials are also being explored by the Wilsons to meet grazing needs in the summer. An example is a mixture of switchgrass, big bluestem, and indiangrass. These perennial warm-season grasses are slow to establish; it typically takes an entire year after seeding before they can be grazed. However, once a stand is productive, it can be kept for decades if managed well. Several of these perennial warm-season grasses are resistant to drought and need warm temperatures for their growth. Some, like switchgrass, eastern gamagrass, and coastal panicgrass, are well adapted to poorly drained soils. Warm-season perennials can be grazed two or three times. Their quality can be sufficient for beef cattle if they are grazed in the vegetative stage, but their quality decreases quickly once they go to head, so it is important to graze them before they go to head. Russ is also testing leguminous and nonleguminous warm-season perennials with the help of Ernst Conservation Seeds (Figure 17). Species mixtures are evaluated for their productivity, quality, soil health benefits, and pollinator habitat. By combining warm- and cool-season perennials and annuals the Wilsons have been able to extend their grazing season to almost 300 days in a year.

Grazing Practices

The Wilsons use intensive rotational grazing. They move their cows several times a day and can increase stock density to 500,000 pounds of live weight per acre. After grazing part of a paddock for a few hours, the cows are moved to another part. The grazed paddock is then rested for 60–80 days before it is grazed again. Intensive rotational grazing has proved to help with better utilization of the pasture. The cows graze the pastures uniformly, which then also regrow uniformly. So there is no need to mow the pastures. There is also less refusal and

Figure 18. Milkweed defoliated by cows. High stock density leads to less selective grazing, which leads to weeds being less of a problem. SJOERD DUIKER

Figure 19. Manure and urine get distributed more uniformly with high stock density grazing than with continuous grazing. SJOERD DUIKER

Figure 20. Water lines have been installed throughout their fields so water is available in every subpaddock. SJOERD DUIKER

Figure 21. Cool-season annual mix ready for grazing. SJOERD DUIKER

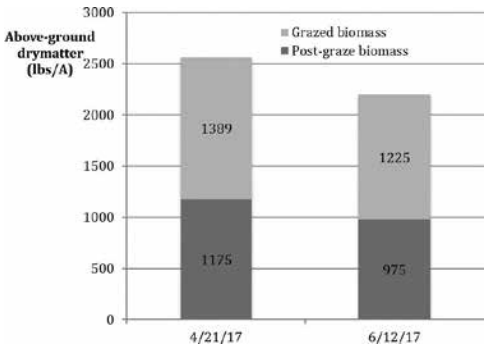


Figure 22. Standing biomass, grazed biomass, and postgrazed biomass of a cool-season annual mixture of rye, annual ryegrass, hairy vetch, white clover, red clover, and crimson clover grazed two times in the spring of 2017. SJOERD DUIKER

loss due to fouling than with continuous grazing. The animals are also less selective when high stock density is used and will defoliate weeds such as horsenettle and milkweed (Figure 18). Hence, weeds don't become a problem on this farm. Finally, manure and urine are distributed more evenly with intensive rotational grazing (Figure 19). Electric mobile fencing is moved every few hours to give the cows a new paddock. The Wilsons also back fence because they are able to move water into the new paddock. Intensity of rotation tends to be lower in the winter because aboveground hoses cannot be used at that time (Figure 20). Grazing is also adaptive, which means that cows are moved when pasture, weather, or soil conditions call for it. By using these grazing practices, the Wilsons have improved the productivity of their farm—they increased the stocking rate from 2.88 acres to 0.96 acre per animal unit and increased the grazing days from 120 to 290 in a year.

Grazing Yields of Alternative Forages

We recorded standing biomass and grazed yield of a select number of fields when Russ grazed them. We also did qualitative soil health testing on some select fields.

Paddock P3C was planted to a mixture of cereal rye, annual ryegrass, hairy vetch, white clover, red clover, and crimson clover on September 7, 2016 (Figure 21). It was grazed twice in April and June 2017. We measured standing biomass and postgrazing biomass in an area on April 21 and June 12 and calculated grazed yield (Figure 22). Standing biomass in April was 2,564 pounds of dry matter per acre, of which 54 percent was grazed (1,389 pounds per acre) and 46 percent left. In June we measured 2,200 pounds of dry matter per acre of standing biomass, of which 56 percent (1,225 pounds of dry matter per acre) was grazed and 44 percent left. Forage quality of the mixture grazed in June was 12.7 percent crude protein, 42 percent acid detergent fiber (ADF), 60 percent amylase-treated neutral detergent fiber (aNDF), 87 relative feed value (RFV), and 56 percent total digestible nutrients (TDN). All together this paddock supplied 2,614 pounds of dry matter per acre in the spring, after which it was terminated, and a summer annual mixture was planted in June.

Paddock F11B was planted to a mixture of switchgrass (seeding rate of 4 pounds per acre), big bluestem (4 pounds per acre), and indiangrass (2 pounds per acre) on July 6, 2012 (Figure 23). It was grazed twice in 2017, in July and September. Typical height of the grass when the animals entered was 38–40 inches. The grass is grazed down to no more than 8 inches to guarantee excellent regrowth and stand longevity. We measured standing biomass and postgrazing biomass in an area on July 5 and September 9 and calculated grazed yield (Figure 24). Standing biomass in July was 6,578 pounds of dry

Figure 23. Warm-season perennial mix of switchgrass, big bluestem, and indiangrass. SJOERD DUIKER

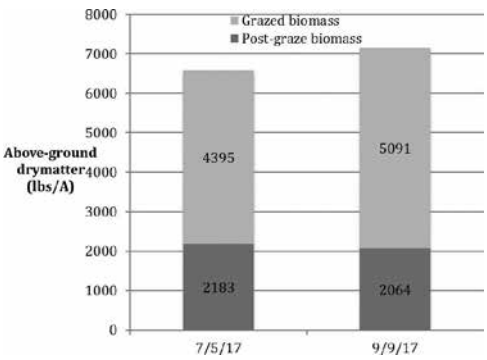


Figure 24. Standing biomass, grazed biomass, and postgrazed biomass of a warm-season perennial mixture of switchgrass, big bluestem, and indiangrass grazed two times in the summer of 2017. SJOERD DUIKER

Figure 25. Summer annual mix of Japanese millet, sorghum, sorghum sudangrass, annual ryegrass, teff, sunflower, mungbean, cowpea, white clover, and red clover being grazed. SJOERD DUIKER

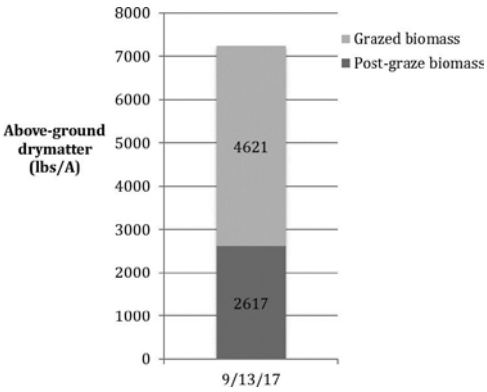


Figure 26. Soil organic matter content (to a 6.5-inch depth) on the Wilson Farm (loss on ignition method, Penn State Lab). SJOERD DUIKER

matter per acre, of which 67 percent was grazed (4,395 pounds per acre) and 33 percent left. In September we measured 7,155 pounds of dry matter per acre of standing biomass, of which 71 percent (5,091 pounds of dry matter per acre) was grazed and 29 percent left. The forage quality of this standing biomass in September was 9 percent crude protein, 42.1 percent ADF, 70.2 percent aNDF (neutral detergent fiber digestibility [NDFD] was 42 percent), 74 RFV, and 62 percent TDN. All together this paddock supplied 9,486 pounds of dry matter per acre in the summer, while more than 2,000 pounds of dry matter per acre was left as food for soil organisms and leaf matter for regrowth.

Paddock F15 was planted to a mixture of Japanese millet on June 6, 2017, after one grazing of cereal rye (Figure 25). It was grazed once, in September 2017. We measured standing biomass and postgrazing biomass in an area on September 13 and calculated grazed yield (Figure 26). Standing biomass in September was 7,238 pounds of dry matter per acre, of which 64 percent was grazed (4,621 pounds per acre) and 36 percent left. Forage quality of this mix was 9.5 percent crude protein, 39.9 percent ADF, 65 percent NDF (NDFD was 68.5 percent), and RFV 83. A cool-season annual mix was planted after this summer annual mix.

Soil Management

The Wilsons take great pride in their soil management. Russ is aware that healthy, productive soil means healthy, productive livestock. He also realizes that soil organisms need to be protected and fed to make the soil healthy and productive. Key soil management principles that the Wilsons use on their farm are as follows:

1. Grazing for strong roots. By typically grazing only 50 percent of vegetation and trampling the rest into the soil or leaving it as a "solar panel" for regrowth, root systems of perennials have been shown to become larger. This helps increase organic matter and build soil structure.
2. Permanent no-tillage. All crops are planted with a no-till drill or no-till planter, or the seed is simply broadcast and trampled into the soil by livestock. Soil is never tilled.
3. Regular soil testing. Soil samples are regularly taken from all paddocks and sent to a reputable soil analytical laboratory. The results and recommendations are evaluated and compared with the performance of the pastures to determine the action to be taken. Manure is the primary resource used to address nutrient deficiencies.
4. Application of agricultural lime to get the pH in the optimal range was one of the first things the Wilsons implemented when they obtained the farm, and they continue to apply agricultural lime as needed to keep the pH in the range of 6.0 to 6.5 (Figure 27).
5. Maintaining soil cover with crop residues or living vegetation. This includes leaving minimum amounts of pasture or crop residue cover to feed soil organisms. The trampling of forage residue into the soil is not considered to be a loss but an essential part of maintaining soil health.

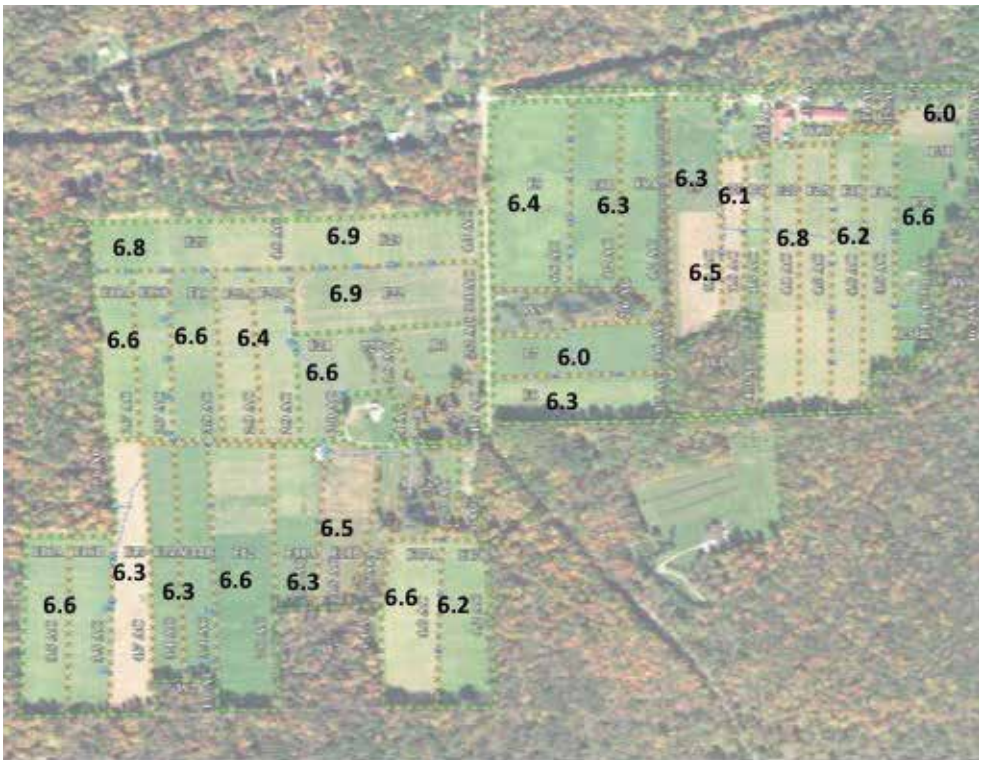


Figure 27. Soil pH on the Wilson farm. pH is corrected using agricultural lime. SJOERD DUIKER

Figure 28. When pugging is noted, animals are put in the covered shed and fed hay. SJOERD DUIKER

6. Maintaining living roots in the soil year-round. The soil is never left bare or empty for long, but new plant mixtures are seeded as soon as possible after a pasture or crop has finished its course.
7. Avoiding the use of insecticides and fungicides and minimizing the use of herbicides as much as possible. The Wilsons are aware that most insects, fungi, bacteria, and viruses are beneficial. Therefore, they don't use any insecticides or fungicides in the pastures or on their animals because of their potentially negative effects on beneficial organisms. They might use them in case an emergency arises, but in general they don't use these. Herbicides are used as a burndown treatment when needed to terminate an annual or perennial pasture. The alternative would be to use the plow, but this is not considered desirable because of the negative effects of soil tillage on beneficial soil organisms and the potential to increase soil erosion.
8. Avoiding soil compaction. Russ tries to avoid putting the livestock in pastures when the soil is too wet. This is mostly judged by observation—when the animal hooves start sinking in the soil, the soil is considered too wet and the animals are removed from that field. The farm has a range of soil types varying in drainage properties, so certain fields can be used for grazing while others may still be too wet. When there is no field that can be used, the cattle are put in the covered shed and fed hay (Figure 28). This does not happen that often anymore because the soil has become quite resilient to compaction through the vigorous root systems of the pasture species and the active soil biological activity. The cows are also in one paddock for a short period of time (hours), after which the pastures are rested for a long period (60–80 days). We evaluated soil compaction before and after a paddock was grazed and observed significant compaction where the animals had tread. This led to significantly reduced infiltration in the grazed paddocks. However, this compacted soil is remediated by the living organisms and roots in the soil because when the paddock is grazed again, the soil is not compacted anymore. It is clear that this is a dynamic process that relies on the life in the soil. The severity of compaction also varies with soil moisture conditions at time of grazing and the vigor of the root system.

Soil Erosion

USDA-NRCS estimated the average annual soil erosion on the Wilson farm using the computer program RUSLE 2. The slope of the fields evaluated ranged from 3 to 4 percent, and the estimated soil loss was calculated assuming a two-year rotation. The scenarios for the soil erosion calculation included corn with a cover crop followed by a fall cover crop mix and a summer forage mix followed by a fall cover crop mix where all crops were established with no-tillage practices. With intensively managed grazing of these forages, the calculated soil loss ranged from 0.10 to 0.13 ton per acre per year, whereas the tolerable soil loss was 3 tons per acre per year. It is clear

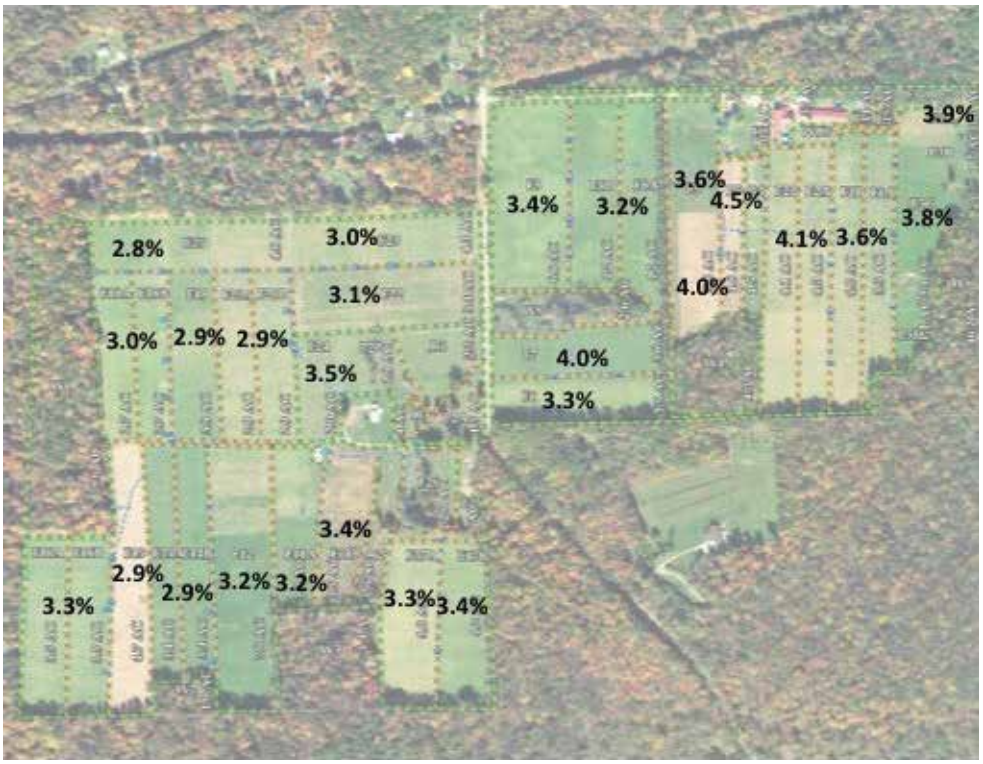


Figure 29. Soil organic matter content on the Wilson farm. SJOERD DUIKER

that with the management employed on the Wilson's farm, soil erosion is almost completely eliminated. This is also confirmed by visual observations.

Soil Organic Matter and Fertility

In March 2017 soil samples were taken on all fields on the Wilson farm and sent to the Penn State Agricultural Analytical Laboratory. The organic matter content in the top 6 inches of soil ranged from 2.9 to 4.5 percent (Figure 29), which is 0.4 to 2 percent above the typical organic matter content in Pennsylvania cropland. The organic matter content is higher on the eastern part of the farm, perhaps because of hay in the rotation and past manure applications close to the barn and that the western side of the farm was managed as cropland with annual crops and intensive tillage before the Wilsons took over the management. We do believe that with Russ's management, soil organic matter content will increase as the years go by.

We measured the available soil phosphorus levels in 2017 and observed that the levels are generally low (mostly 10–20 ppm). For reference, 14 ppm or more of P is considered sufficient for perennial warm-season grasses, but 27 ppm of P is considered the minimum needed for cool-season pasture or many annuals. The soil P levels continue to be monitored by the Wilsons. Because pasture productivity is good and no visible phosphorus deficiency is observed, they have not yet addressed this issue. The thought is that high soil biological activity may make more phosphorus available than what the soil test gives credit for. For example, large root systems with many fine roots are known to make phosphorus more available, and the grazing practices used by the Wilsons stimulate vigorous root systems. Mycorrhizae are also known to increase phosphorus uptake, and these are favored by the practices used on this farm. Some species, such as buckwheat, are known to liberalize phosphorus, and this species is used in some annual mixes.

Conclusion

Wilson Land & Cattle is an innovative farming operation that uses more than 70 plant species to feed their ruminant animals almost year-round by grazing. The farming practices used have dramatically reduced the cost of fertilizers, machinery, and fossil fuel. By focusing on soil health, the farm has been able to improve their stocking rates and increase grazing yields to extend the grazing season to almost 300 days a year.

Prepared by Sjoerd W. Duiker, professor of soil management and applied soil physics, and Russ Wilson, owner, Wilson Land & Cattle.

This material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture; under number 68-2D37-14-743.

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

extension.psu.edu

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Where trade names appear, no discrimination is intended, and no endorsement by Penn State Extension is implied.

This publication is available in alternative media on request.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability, or protected veteran status.

Produced by Ag Communications and Marketing

© The Pennsylvania State University 2018

Code EE0236 11/18pod