Establishing Cover Crops, Refugia and Field Borders Adjacent to Crop Fields

Evaluating the Impacts on Soil Health, Arthropod Diversity, Wildlife Habitat and Potential Economic Benefits

Extension
University of Missouri

MP936

This case study was conducted at the MU Bradford Research Center (now the MU Central Missouri Research, Extension and Education Center), located near Columbia, Missouri; and at various locations across the state to provide information on the effects of establishing cover crops as part of a conventional soybean/corn crop-rotation system, coupled with the establishment and management of adjacent field borders had on selected soil health parameters; refugia for arthropods, including insects and pollinators; wildlife habitat; and potential economic benefits.

We use the terms “refugium” and its plural “refugia” to describe an area with a plant community that provides the habitat conditions that support arthropod diversity over a period of time. Refugium is a more specific scientific term for an area that provides stable conditions over long periods of time, allowing a population or species to survive and persist through a major, long-term environmental change.

Authors

Tim Reinbott, Director of Field Operations, MU South Farm and Research Center

Robert Pierce, Associate Extension Professor, State Wildlife and Fisheries Specialist

Ray Wright, Research Associate, formerly with the University of Missouri

Terryl Woods, Research Specialist, MU Division of Plant Sciences and Technology

Deborah Finke, Professor, MU Division of Plant Sciences and Technology

Ryan Milhollin, Assistant Extension Professor, Agriculture Business and Policy

Andrew Kientzy, Business Specialist, Agricultural Business and Policy Extension

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Contents

Introduction

Cover crops have been used in the Midwest as part of a crop rotation system for their potential of improving soil health and numerous other crop production and conservation benefits. There continues to be interest in integrating soil conservation practices and establishing habitats that are also beneficial for wildlife and pollinators within the agricultural landscape in Missouri.

Historically, cover crops have had minimal use in traditional corn and soybean production, and these crops have often been produced in fields fencerow to fencerow, resulting in little habitat for pollinators or wildlife (Figure 1a). However, conservation programs have been developed to encourage producers to implement conservation practices that feature field borders and create refugia around crop fields for wildlife and pollinators (Figure 1b).

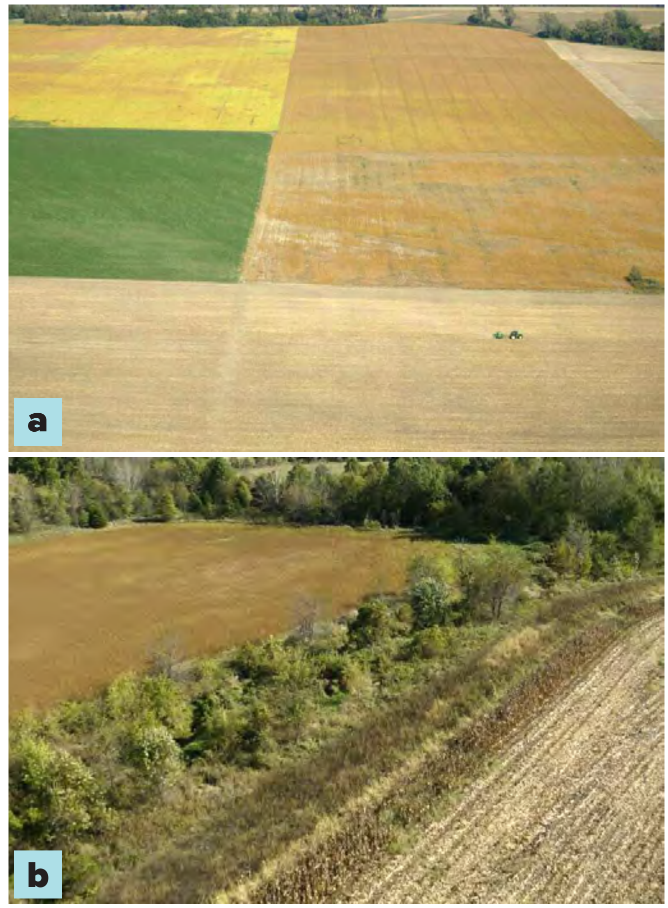

Figure 1. (a) Row crops established from fencerow to fencerow within agricultural landscapes have reduced available habitats for pollinators and wildlife dependent on early successional native vegetation that provide food and cover. (b) However, conservation programs have been developed to promote field borders around crop fields for wildlife and pollinator habitats.

In the past, little concern was paid to how certain agricultural production practices impacted soil health. Soil health indicators focus on soil biology, microorganisms and their habitat, and chemical and physical properties of soil. These indicators are greatly affected by soil tillage practices that leave little crop residue, vegetation or cover remaining on the soil surface. Such tillage practices have resulted in greater rates of soil erosion, destruction of the soil structure, and a general loss of water holding capacity, negatively affecting crop production and the environment (Figure 2).

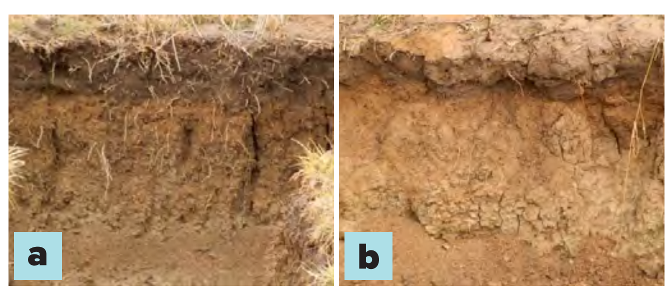

Figure 2. Soil profile from (a) a soil that has been under perennial cover for more than 60 years compared to (b) soil only 30 feet away that has been extensively tilled each year.

In recent years, there has been tremendous interest in promoting agriculture production systems that improve many of the parameters that are indicators of soil health. According to the U.S. Department of Agriculture (USDA) Census for Agriculture, an estimated 18 million acres out of 900 million acres of farmland in the United States were planted to a cover crop in 2023. About 1 million acres of crop land in Missouri included cover crops in the rotation. Although cover crop acreage continues to increase each year, there remains a significant amount of acreage that could benefit from the establishment of cover crops as well as from other conservation practices. For example, the University of Missouri Center for Regenerative Agriculture has funding to help defray costs of establishing cover crops for agriculture producers and landowners and links to those programs are found in the “additional resources” section.

One of the objectives of this case study was to determine how soil health is impacted by different crop production management systems, including use of no-till and cover crops, and how field edges and refugia established with native plantings around crop fields influence arthropod diversity, including insects and pollinators, and wildlife habitat (Figure 3).

Figure 3. Establishing a (a) cool-season (crimson clover pictured) or (b) warm-season cover crop with the creation of field borders can improve row-crop yields, benefit arthropod diversity and improve habitats for wildlife.

How these management systems affect soil function, row-crop yield and potential profitability is important for agriculture producers to consider before implementing various conservation practices. Besides improving soil health, these practices can positively affect a suite of arthropods, including insect species — many of which serve as pollinators — as well as many species of ground nesting birds, including grassland songbirds and bobwhite quail, and other wildlife (Figure 4).

Figure 4. (a) Field borders composed of herbaceous vegetation provide beneficial habitats for a variety of wildlife, (b) including ground-nesting birds such as bobwhite quail.

Many species of grassland birds have been in decline for decades within the agricultural landscape due to land-use changes that promote a loss of habitat, changes such as increased urbanization or the elimination of habitats due to improved crop production methods. However, future agriculture policies will most likely offer new conservation programs for landowners to implement that will influence the adoption of cover crops that promote environmental benefits. The promotion of regenerative agriculture and the adoption of climate-smart agricultural practices is expected to increase over the next several years. In addition, many agriculture businesses have developed carbon markets, offering carbon farming programs that pay crop producers for capturing soil carbon by planting cover crops and reducing tillage.

Case study objectives

The overall objective of this three-year case study was to gather information that determined whether crop management systems using cover crops, coupled with the creation of adjacent refugia and field borders, might provide an opportunity to improve soil health as well as enhance habitats for beneficial arthropods and wildlife. Our efforts also focused on developing demonstrations to extend information to agricultural producers and support conservation with innovative and holistic approaches that also might increase profitability. Realizing that crop yields could not be improved by simply planting a cover crop, we addressed a more holistic approach that highlighted conservation practices involving cover crops that influenced soil health. This case study also examined the influence of establishing refugia of native vegetation on arthropod diversity and wildlife habitat adjacent to crop fields that used a suite of both spring and summer cover crops (Figure 5).

Figure 5. An example of (a) a 30-foot wide field border and refugia, established adjacent to (b) a woodland and crop field using a variety of native forbs and legumes to provide benefits for wildlife as well as for a diversity of insects.

Case study methods

General overview and study area

Missouri's natural resources are incredibly diverse, due in part to the diversity of soils and geographies that support a variety of soil types, each influencing the plant community that exists in a particular area. Demonstrations were established with cooperators within various regions of the state and efforts focused on implementing and monitoring cover cropping practices and determining how these practices influenced such parameters as soil health; arthropod diversity, including insect and pollinator diversity; and wildlife habitat. Fields on University of Missouri Research Extension and Education Center property, of participating private landowners, and on selected Missouri Department of Conservation Areas were also used. As part of this case study, we documented the arthropod abundance and diversity that was found within 30-foot field border strips as well as within row-crop systems that used cover crops. Evaluations were then conducted to determine and rate the quality of the wildlife habitat that was created as a result of implementing the various field treatments.

Locations for collecting soil health information

The USDA Natural Resource Conservation Service (NRCS) classifies the general soil attributes within various regions by Major Land Resource Areas (MLRA). Locations in which data was collected are depicted in Figure 6. A description of the MLRAs and a classification of soils in the region in which soil samples were collected for soil health information follows. Refer to [Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin (PDF)][1] (USDA Agriculture Handbook 296, 2022) for

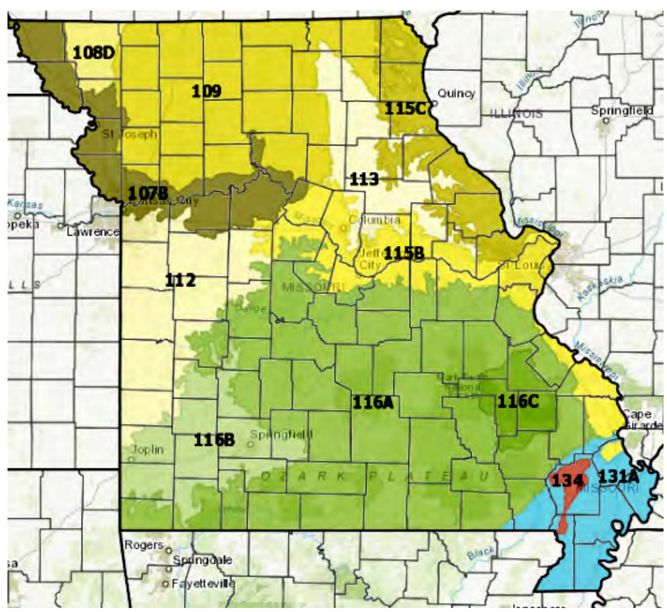

Figure 6. Missouri map depicting the 12 major land resource areas (MLRAs) that are located across the state. Demonstrations were developed and information collected in MLRAs 109 (North Missouri), 113 (Central Missouri), 131A (Southeast Missouri) and 112 (Southwest Missouri).

more on MLRAs and for definitions of soil-related terms used in the MLRA descriptions below.

MLRA 109 (North Missouri): Iowa and Missouri Heavy Till Plain

The dominant soil orders in this MLRA are Alfisols, Entisols and Mollisols. The soils in the area have a mesic temperature regime, an aquic or udic moisture regime, and mixed or smectitic mineralogy. They generally are very deep, well drained to poorly drained, and loamy or clayey.

MLRA 113 (Central Missouri): Central Claypan Areas

The dominant soil order in this MLRA is Alfisols. The soils in the area have a mesic soil temperature regime, an aquic or udic soil moisture regime, and mixed or smectitic mineralogy. They generally are very deep; well drained to poorly drained; and loamy, silty or clayey.

MLRA 131A (Southeast Missouri): Southern Mississippi River Alluvium

The dominant soil orders in this MLRA are Alfisols, Vertisols, Inceptisols and Entisols. The soils in the area dominantly have an aquic moisture regime, smectitic clay mineralogy, and mixed sand and silt fraction mineralogy. They are very deep, dominantly poorly drained or somewhat poorly drained, and dominantly loamy or clayey.

MLRA 112 (Southwest Missouri): Cherokee Prairies

The dominant soil orders in this MLRA are Mollisols and, to a lesser extent, Alfisols and Vertisols. The soils in the area dominantly have an aquic or udic soil moisture regime; and mixed, smectitic or siliceous mineralogy. They generally are moderately deep to very deep; well drained to poorly drained; and loamy, silty or clayey.

Methods used for collecting soil samples and measuring impacts on soil health parameters

Soil management can influence soil health parameters within the soil profile. Information was collected from fields in the MLRAs identified. Samples were collected at various depths and submitted to the MU Soil Health Assessment Center[2] for analysis.

The following soil health data was collected:

- Soil biology — phospholipid fatty acid (PLFA), which measures the diversity and weight of individual soil microorganisms; arbuscular mycorrhizal fungi (AMF); and predator–prey measurements expressed as a ratio
- Soil physical properties — bulk density (BD) and water stable aggregate stability
- Soil chemical property — active carbon (POX-C)

The analysis of soil health parameters in a soil is variable and changes with soil type and overall climate. Comparisons were made that focused on general trends to simplify the interactions and address any inherent variability. Past research has documented that these soil parameters provide useful information and serve as important measures of soil health; a more thorough description of these parameters and a summary of the data collected follows.

PLFA measurements

Phospholipid fatty acid (PLFA) measurements are used to estimate the individual and total microorganism biomass in a soil profile. This information can be used to evaluate changes in the composition of the microbiota with the soil environment. Within the 0-to-6-inch depth, PLFA values were greater than those in the 6-to-12-inch depths. Each of these locations was managed with minimal disturbance to the soil through no-till and with the management of perennial vegetation. This type of minimal soil disturbance promotes the microbial community and allows it to flourish. Other factors — such as topsoil depths, organic matter and nutrient contents — can affect these values as well. However, by examining trends we demonstrated that using cover crops in a no-till system resulted in similar microbial biomass values in the top 6 inches as found in soils in fields that were in perennial vegetation, such as those established through the Conservation Reserve Program (CRP). PLFA total weight values of soils that had cover crops as part of the rotation were just slightly less than the prairie field sites that were used during the project and greater than the values found within the CRP fields.

There was little difference in soil microorganism weight within the 6-to-12-inch depth from the different row-cropping systems that were used (Figure 7a). However, the CRP and prairie fields had greater soil microorganism mass in the 6-to-12-inch depth than did the row-crop systems, indicating that perennial vegetation has a greater capability to improve the soil microorganism mass at deeper soil profiles. Native warm-season grasses and forbs have deeper root systems and a larger turnover of root mass at these soil depths as compared with annual row crops. A limiting factor within the deeper soil profile can be a lack of a food source for microorganisms, or organic matter, as well as a lack of soil oxygen. These lacks can be due to greater bulk density values or higher clay contents.

In addition, soils that have been in a row-crop system for numerous years have typically lost much of their original topsoil and have developed tillage pans below the 6-inch depth. These conditions are also are unfavorable for soil microorganisms. Because of their perennial life cycle and deep roots, native-warm season grasses and forbs planted in either a CRP or reconstructed prairie field can offset some of these lower-quality soil quality factors.

When compared with different soil and crop management situations in fields across Missouri, there was little increase in PLFA values that were due to cover crop treatments (Figure 7b). This is not surprising because most of these fields were in the first or second year of having a cover crop established and significant changes in PLFA values are often not observed until year four of cover crop use. PLFA weight was also less when compared to a pasture or to a restored prairie field that was converted to perennial vegetation through the CRP. The lack of greater response in PLFA weight in CRP fields may be from a lack of diversity of plant species compared to the restored prairie. The pasture was planted with cool-season grasses. Research has shown that fields with cool-season perennial grasses have high PLFA values because they

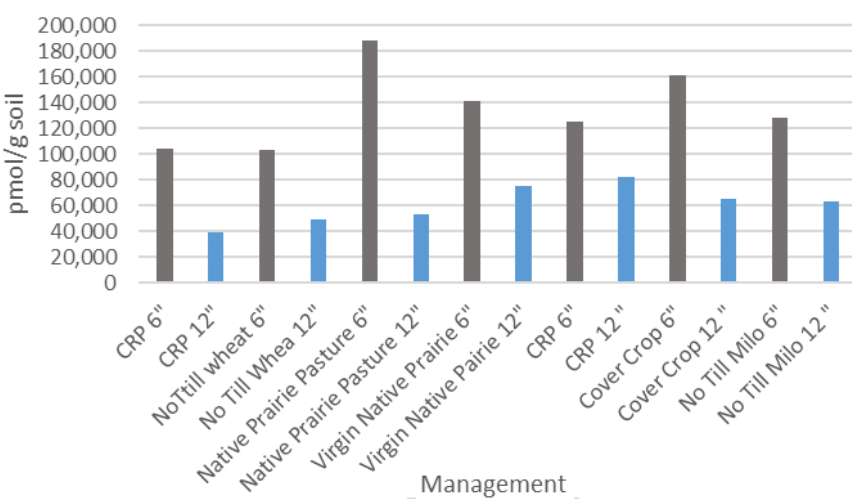

Figure 7a. Total PLFA weight, measured in picomoles per gram of soil, from multiple cooperator fields across Missouri representing different soil management practices across multiple locations and MLRAs. PLFA measurements were taken at soil depths of 0 to 6 inches and 6 to 12 inches.

remain green for most of the year, providing a food source for microorganisms through secretions from the root systems.

Interestingly, PLFA weights of soils were much less in Southeast Missouri compared to the other locations. This difference may be due to higher soil temperatures and sandy soils (Figure 6 and Figure 7b). These adverse climatic conditions result in organic matter being rapidly broken down over a short period of time.

Active carbon is a component of relatively fresh organic matter that provides an important food source for soil microorganisms and is easily broken down. Thus, active carbon is highly associated with organic matter and tends to increase as soil organic matter increases (Figure 7c). Active carbon values were also lower in soils from southeast Missouri compared to north and southwest Missouri (Figure 7d) and correlates well with PLFA weights from those areas (Figure 7b).

To quantify how soil management affects soil properties, soil penetrometer readings from each of the different management systems were compared. Soil penetrometer readings from the three field locations at Shawnee Trail Conservation Area in southwest Missouri are an indication of how many inch-pounds are needed to penetrate the soil at specific depths (Table 1). The penetrometer system used had a maximum reading of 300 inch-pounds of pressure. When that level is reached, the penetrometer collection is stopped to protect the equipment from damage. The level of compaction may limit the microbial activity between native nonpastured restored prairie and pastured restored prairie. Soil resistance pressure in the pastured prairie was 150 inch-pounds at a 3-inch depth and maxed out at a 6-inch depth throughout the soil profile. However, the soil resistance pressure of the nonpastured native prairie never reached 150 inch-pounds throughout

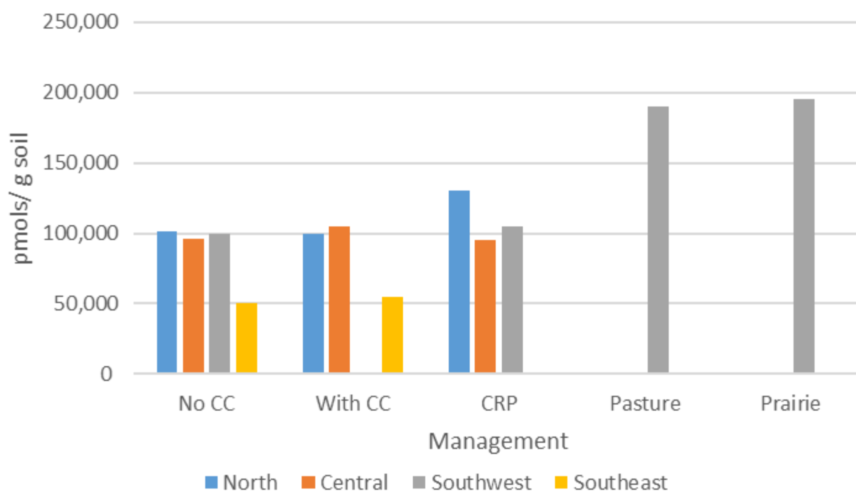

Figure 7b. PLFA weights, measured in picomoles per gram, across multiple crop and soil management situations in different geographical areas of Missouri. Management included annual an cropping system of a corn/soybean rotation either with or without an annual winter cover crop, CRP, cool-season pasture and native prairie.

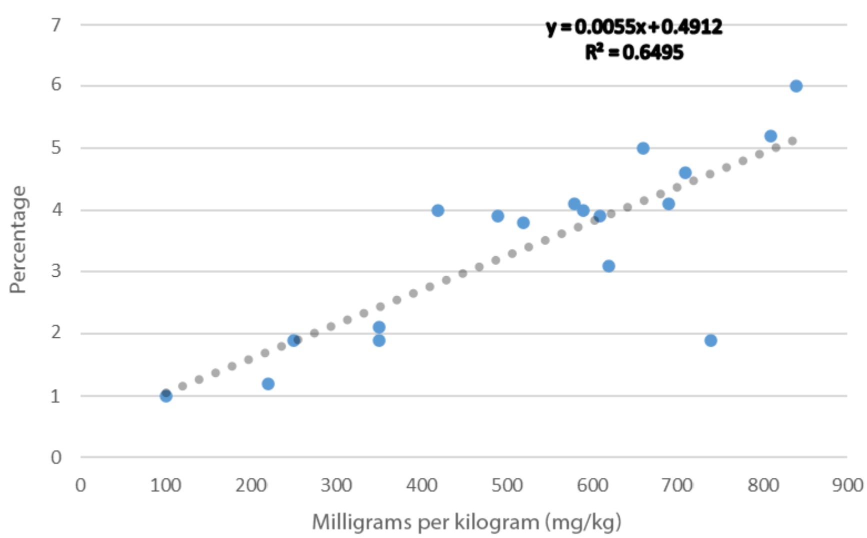

Figure 7c. The interaction between active carbon values and soil organic matter.

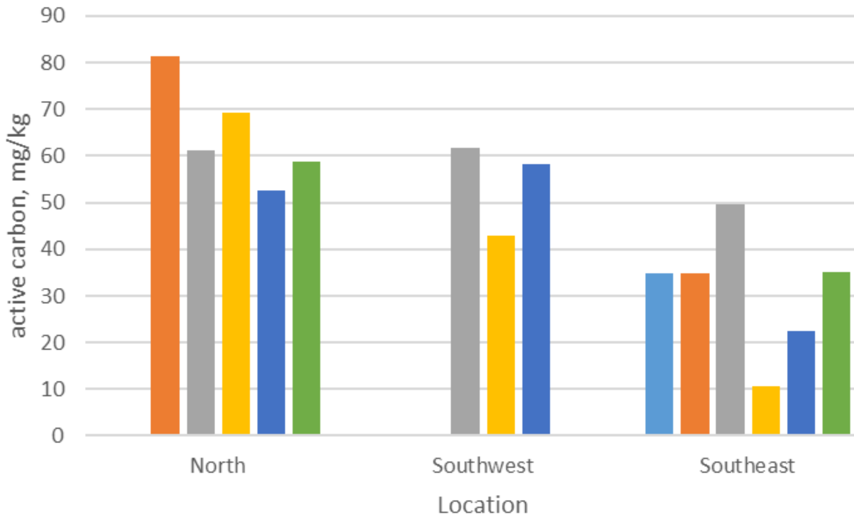

Figure 7d. Active carbon levels across different areas of Missouri.

Table 1. Penetrometer readings for Shawnee Trail Conservation Area representing soil management on prairie soils (MLRA 112) in southwest Missouri compared to a fallow grain crop field.[1]

Measurement depth (inches)	Virgin native prairie	Fallow crop field	Prairie with cattle
3	50	100	150
6	75	150	300
9	120	250	300⁺
12	150	300	300⁺
15	150	300⁺	300⁺

1. Readings were collected at 3-inch intervals until 300-inch pounds were achieved.
\+ Reached penetrometer maximum.

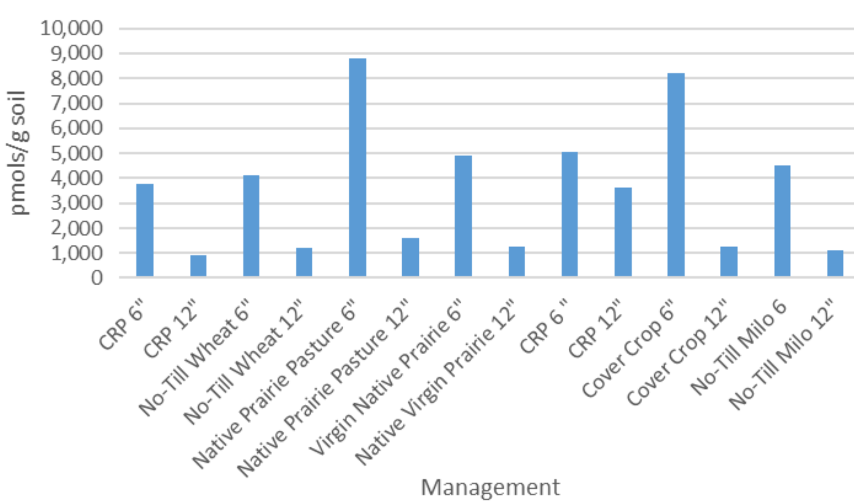

Figure 8. Arbuscular mycorrhizal fungi (AMF) collection from multiple cooperators fields in Missouri representing different soil management across multiple locations. Measurements were taken at soil depths of 0 to 6 inches and 6 to 12 inches.

the measurement depth. These results indicate that livestock compaction can be significant and is even greater than compaction of fields in crop production.

Arbuscular fungi measurements

Arbuscular mycorrhizal fungi (AMF) symbiotically inhabit the root cortical cells of most plants and obtain carbon from their hosts. The mycelia of the fungi can expand the root area up to three times greater than that of the host roots, transferring nutrients such as phosphorus and water.

AMF primarily occupy the top 0 to 6 inches of the soil profile regardless of how the soil is managed (Figure 8). Surprisingly, within the 0-to-6-inch depth, virgin native prairies and native prairie pastures have similar values as those of row-crop fields that use cover crops. The greater AMF numbers in the undisturbed pasture and cover crop fields could be associated with the diversity of plants in these fields, which increases the potential for a constant turnover of the root systems.

Cover crops systems are planted annually with a mixture of legumes and cereal grasses, such as winter wheat. In eroded soils, this vegetation provides a diverse rooting system and promotes an increase in nutrient cycling, resulting in a fungal dominant ecosystem. A similar relationship occurs when there is an increased number of insects in an area when a new food source is provided and then a decline in numbers as those food sources become unavailable. Surprisingly, the nongrazed native prairie AMF values are not higher, which may reflect a stabilized soil environment with more bacterial abundance. Cover crop systems have high AMF values, supporting the concept of an increase in biodiversity. Soils at the 6-to-12-inch depth follow an expected pattern of greatly reduced AMF values excluding the one CRP collection.

Predator–prey measurements

The predator–prey ratio is a relatively new technique developed to describe the predator and prey balance of the soil microbial community. The predator–prey ratio is calculated as the total weight of protozoa to the total weight of bacteria within a soil sample. Protozoa consume bacteria and release nitrogen and other nutrients back into the soil. A system that has little new fertilizer input, manures or use of legumes is stable in its predator–prey ratio as exhibited with the values of a virgin native prairie (Figure 9). However, in a fertilized crop field or a field composed of legume cover crops, a flush of bacteria occurs, followed by a later flush of protozoa. These soil measurements are a snapshot in time; however, this data clearly shows that where cover crops are used or livestock are present, protozoa numbers have responded to greater nitrogen inputs and the resulting increase in bacteria, leading to higher predator–prey ratios.

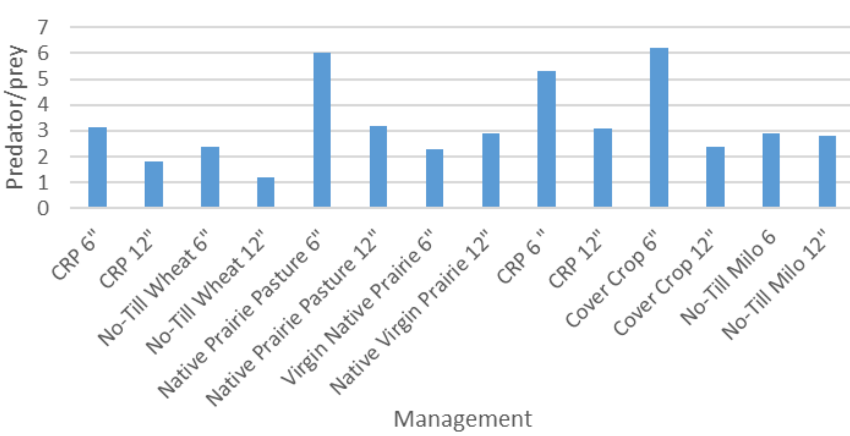

Figure 9. Predator–prey ratios from multiple cooperators fields in Missouri representing different soil management practices across multiple locations. Ratio measurements were taken from soil depths of 0 to 6 inches and 6 to 12 inches.

Soil physical properties

Bulk density measurements

Bulk density (BD) values can be an indicator of the level of soil compaction or a lack of soil structure, particularly when compared across similar soil types. Bulk density values are collected from the upper 3 inches of the soil profile. It is calculated as the soil dry weight divided by its volume. The less dense the soil, the greater its potential for better water infiltration, soil aeration and root development, whereas when BD measures are greater, these environmental values are inhibited, which affects overall soil health. These values are generally higher in fields that are cropped annually (Figure 10). Even in no-till operations, BD is greater than expected because the soil is compacted by equipment operations.

Cover cropping systems have slightly lower BD values when compared to other cropping systems. Even a small decrease in BD can make a large difference in environmental services. The range of BD values that results from these particular management practices is very small. The average BD from Missouri soils is 1.1 gram per cubic centimeter, and the BD from cover crop systems is below that average.

Conversely, BD values in no-till systems are either at or slightly above that average due to equipment use. The native prairie values are the lowest, which is expected in an undisturbed management system. Livestock grazing in a restored

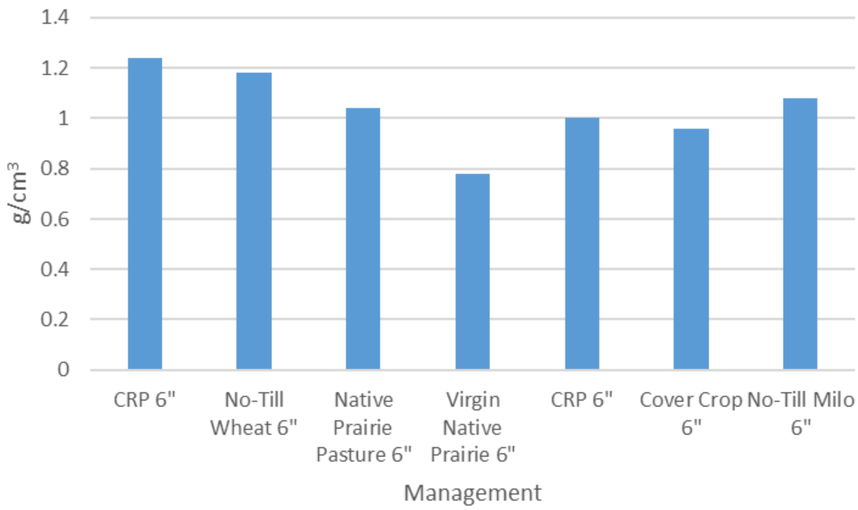

Figure 10. Bulk density measurements collected from multiple cooperators fields in Missouri representing different soil management practices across multiple locations. Measurements were taken at a soil depth of from 0 to 6 inches.

At historic Sanborn Field (located on the University of Missouri campus in Columbia, Missouri), long-term treatments over more than 50 years demonstrate that no-till and lengthening the crop rotation improves WAS and active carbon compared to heavy tillage, but the resulting WAS values are still less than half of those found in a restored prairie (Table 2). Shorter-term studies of less than 10 years at the nearby Central Missouri Research, Extension and Education Center demonstrate that tilling soils decreases WAS, but it

prairie, although light, resulted in a higher BD value than prairie without grazing. Comparing restored prairie BD values to those of annual cropping systems provides an expectation of how agriculture equipment can impact BD values. Even slight changes in BD values from improved soil management takes time, but when a perennial crop is planted, the change occurs much more quickly — some of the CRP fields used as a comparison were established only three years prior to the initiation of the case study.

Water aggregate stability measurements

Water aggregate stability (WAS) is an important measurement of a soil's physical properties. It indicates how resistant the soil structure will be to breakdown from rainfall and provides insight into the soil's water and aeration properties. Higher WAS values are often associated with greater rainwater infiltration and water holding capacity. WAS is correlated with active carbon because the mycelium and glomalin produced by soil microorganisms holds soil aggregates together, thus increasing the WAS (Tables 2 and 3). As previously noted, active carbon is a food source for soil microorganisms.

Table 2. Soil health factors at Sanborn Field after long-term[1] rotation and tillage treatments.

Treatment	Active carbon (mg/kg)	Aggregate stability (percent)
Continuous tilled corn, commercial fertilizer	270	13
Continuous no-till corn, commercial fertilizer	423	19
Corn/Wheat/Red clover, commercial fertilizer	414	22
Restored prairie	463	51

1. Fifty or more years.

Table 3. Soil health factors at the Central Missouri Research, Extension and Education Center after nine years of different rotations, tillage and plant species.

Treatment	Active carbon (mg/kg)	Aggregate stability (percent)
Soybean, no-till	411	28
Soybean, tilled	365	21
Red clover[1]	517	40
Tall fescue	585	72
Switchgrass	523	65

1. A corn, soybean, wheat and red clover rotation.

greatly improves when a perennial crop is added to the rotation. This corresponds with information obtained from studies conducted at Sanborn Field that compared WAS values from crop fields with perennial crops, such as tall fescue and switchgrass. The WAS values in soils treated with a perennial crop were twice that of soils treated with an annual grain crop.

Summary of soil health measurements

Understanding the roles and functions of the four soil health measurements used during this case study — PLFA weights, BD, AMF and predator–prey ratios — and how soil management affects these values is important for making sound soil health decisions. These interactions indicate that soil disturbance greatly influences the values of these various soil health parameters, making it difficult for row-crop fields to achieve the soil health values that are found in native prairies.

Soil health parameters can be improved and the soil microbial community can be enhanced through soil conservation practices, including the use of no-till and the establishment of cover crops. Adding cover crops to an annual row-crop production system improved these soil health parameters by adding stability to the microbial community, resulting in an improved soil structure through lower BD values.

Description of the cover crops, field treatments and management techniques implemented

Cover crops were established in crop production fields as a part of a crop rotation system at the MU Bradford Research Center (now the Central Missouri Research, Extension and Education Center) near Columbia, Missouri. These were established as either monoculture plantings or using diverse mixtures of plants, a polyculture, to examine impacts of using cover crops and evaluating their potential conservation benefits. Cover crops were established using no-till techniques or overseeded directly into the crop. Species used and seeding rates are found in Table 4.

The following management techniques were implemented to determine the impacts of various cover cropping situations on crop yield, arthropod use, and wildlife habitat:

- Comparison of crop fields established in winter wheat in the fall and then double-cropped with soybeans after wheat harvest with fields that were established with a summer cover crop after wheat harvest
- Overseeding a polyculture of forbs and legumes — partridge pea, plains coreopsis, sunflower ox-eye, Korean lespedeza and red clover — into wheat in early March
- Planting a polyculture of winter annual cover crops after corn harvest in October

During the case study, these various crop and vegetation management situations were categorized as a treatment. Arthropod diversity, including insects and pollinators, and wildlife habitat information was collected for each of these treatments, which are defined as follows:

- Conventional corn and soybean rotation
- No-till corn and soybean rotation with cover crops
- No-till winter wheat with double-cropped soybeans or summer cover crop
- No-till winter wheat
- Traditional CRP grass field with a 10 native species mix
- Traditional CRP grass field with a five cover crop species mix
- Pollinator habitat (refugia) unburned
- Pollinator habitat (refugia) after a controlled fire

Table 4. Cover crops used and seeding rates.

Polyculture seeded after corn harvest	Typical monoculture rate (pounds per acre)	Experimental polyculture rate (pounds per acre)
Cereal rye	90	15
Oats	48	8
Tillage radish	9	1.5
Crimson clover	20	3
Austrian winter pea	60	10
Hairy vetch	30	5
Overseeded polycultures into wheat	**Typical monoculture rate (seeds per square foot)**	**Experimental polyculture rate (seeds per square foot)**
Partridge pea	50	10
Plains coreopsis	50	10
Ashy sunflower	50	10
Korean lespedeza	50	10
Red clover	50	10
Summer cover crops	**Typical monoculture rate (pounds per acre)**	**Experimental polyculture rate (pounds per acre)**
Pearl millet	6	1.5
German millet	6	1.5
Foxtail millet	6	1.5
Buckwheat	10	1.5
Sorghum sudangrass	8	2.0
Triticale	60	15.0
Sunflower	10	2.5
Sesbania	20	5.0
Cowpea	40	10.0
Sunn hemp	20	5.0

Methods for collecting and evaluating the impacts of treatments on arthropod diversity, including insects, and wildlife habitat

Populations of arthropods, including those that are insect pollinators, and wildlife require appropriate types of habitats to reproduce and survive.

Arthropods (phylum Arthropoda) are the most diverse group in the animal kingdom as about 85% of all animal species are members of this phylum. This phylum includes all species of insects, spiders and mites. About two-thirds of all flowering plants are pollinated by arthropods, primarily insects.

Unfortunately, in many areas, habitats that support this diversity within the agricultural landscape have been negatively impacted by a suite of practices, previously described, that reduce the availability of vegetation that provides food and cover.

Thus, this case study also focused on the potential of cover crops being used to improve habitats that support greater arthropod diversity, including insect pollinators, and for ground-nesting birds, such as bobwhite quail. Native forbs are extremely valuable in providing nectar and pollen for many species of insect pollinators. However, to take full advantage of their presence, it is important that the flowering times of native species coincide with the life cycle of a diversity of pollinators. Native forbs also produce seeds that are a food source for wildlife during fall, winter and early spring. In addition, they provide cover and attract insects that serve as a food source for ground-nesting birds.

Arthropod diversity

Information on arthropod diversity — insects and spiders — was collected by sampling locations within each of the crop fields that used various cover crop treatments during the growing season as well as within areas of the field edges that were adjacent to the crop. Thirty-foot wide field borders were established along selected field edges to serve as refugia for beneficial insects, including pollinators, and to provide food and cover for wildlife.

Previous observations indicated that summer and winter annual cover crops provide many of the same bloom window times and are as attractive to pollinators as native plants. Species such as hairy vetch and other winter annual cover crops and summer annual cover crops were planted sequentially on adjacent sides of existing field borders that were composed of native forbs for comparison.

In addition, an insect pollinator diversity demonstration was established that consisted of a 12-species wildflower-and-forb mix of plants with various bloom times (Table 5). This demonstration plot was established as a field border adjacent to a field using a conventional corn/soybean/wheat rotation. Throughout the spring and summer, the number of arthropod species, including those that are pollinators, and other beneficial insects was determined within the fields that used the cover crop mixes and compared with the number found in the fields with the traditional row-crop field treatment.

Table 5. Flowering time of selected native wildflower and forb species mix.

	Flowering time		
Species	March–May	June–Aug	Sept–Nov
Blackeyed Susan		x	x
Coneflower, purple	x	x	
Coneflower, gray-headed		x	x
Partridge pea	x	x	
Rattlesnake master		x	
Sunflower, ox-eye	x	x	x
Sunflower, ashy		x	
Clover, purple prairie		x	x
Foxglove beardtongue	x	x	
Prairie blazing star		x	
Blue sage		x	x
Stiff goldenrod			x

Weekly insect observations were made and recorded. Because native bees are such important pollinators, special notation was given to that group of species. Arthropods were sampled using the following procedures:

- Sweep nets were used during the summer to assess species diversity, activity and abundance.
- Adjacent control sites — for example, corn, soybeans, cool-season grass pasture — were sampled to provide comparative data under those cropping regimes.

An additional demonstration plot was established using winter and summer annual cover crops adjacent to a field that was in organic vegetable production. Arthropod diversity information was also collected at this location.

At the Shawnee Trail Conservation Area, a Missouri Department of Conservation Area located in southwest Missouri, winter and summer cover crops were established in crop fields and field borders were left. Diversity information was also collected at this location.

Data from sweep net collections conducted every two weeks was obtained at these nine sites representing several different habitat types. Identification of arthropods within two classes, Insecta and Arachnida, was completed to the order level. Within the order classification, there can be variation of beneficial and nonbeneficial insects, however, the focus of this case study was on how the various orders responded to different management situations.

Arthropods within the class Arachnida and class Insecta were grouped by order:

- Araneae — spiders
- Coleoptera — beetles
- Lepidoptera — butterflies and moths
- Diptera — flies
- Hymenoptera — wasps, bees, ants
- Orthoptera — grasshoppers, crickets
- Hemiptera — true bugs, including plant bugs, stink bugs; scale insects, mealybugs, leafhoppers, aphids
- Neuroptera — lacewings
- Thysanoptera — thrips

To simplify the presentation of the data, figures developed are based on determining a monthly cumulative abundance instead of individual collections. This information was used to compare the affects of various agricultural management practices on the insect community over time. Figures 11 to 18 depict the results of these collections and provide a comparison of how the arthropod community responded to the various land management systems.

Arthropod data collected in fields using traditional corn and soybean rotations

Figures 11 and 12 represent the arthropod collections that were made in corn and soybean crop rotations, which is the dominant row-crop rotation used in Missouri. Figure 11 represents arthropods collected within a traditional tilled corn and soybean rotation with no cover crops, and Figure 12 represents a corn and soybean rotation using no-till establishment techniques and a cover crop mixture planted during the rotation.

These fields were established as a side-by-side comparison and one of the most notable trends observed were the differences in the abundance of insects and number of orders that were found. Averages were twice as high in the cover crop fields than in the traditional row-crop fields. Low numbers of insects were consistent through-out each treatment that used the traditional row-crop system, without cover crops in the rotation. Within the crop fields where a cover crop was part of the rotation, insect populations were much higher, as adjusted with the season and the growth stage of the cash crop.

For example, during May and June, the abundance of arthropods, including spiders, was almost three times higher in the cover crop system than in the fields without cover crops during the rotation. Like the soil microbial community, the aboveground insect community responded positively to the presence of a cover crop. The nectar and pollen food sources and the habitat provided by the cover crops during the early season, April and May, accounted for these greater numbers, but arthropod numbers drop to almost the same level as those found in the traditional row-crop fields without a cover crop later during the summer, July and August. Once the aboveground influence of the cover crop vegetation was terminated, the cash row-crop systems provided only a monoculture of food and habitat, which did not support diverse insect populations. This indicates that there is a need for diversified refugia in place for arthropods to use during the summer months.

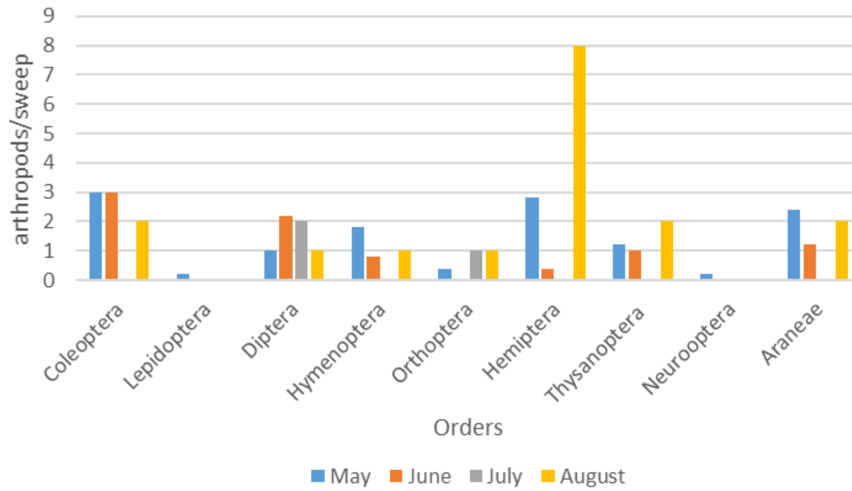

Figure 11. Sweep net arthropod collections, by month, are expressed by average number of spiders (Araneae) and insects by order, for traditional corn and soybean rotations. These data provide a seasonal population response from a traditional corn/soybean cropping system without a cover crop. Eight insect orders and spiders (Araneae) were used to measure the arthropod response.

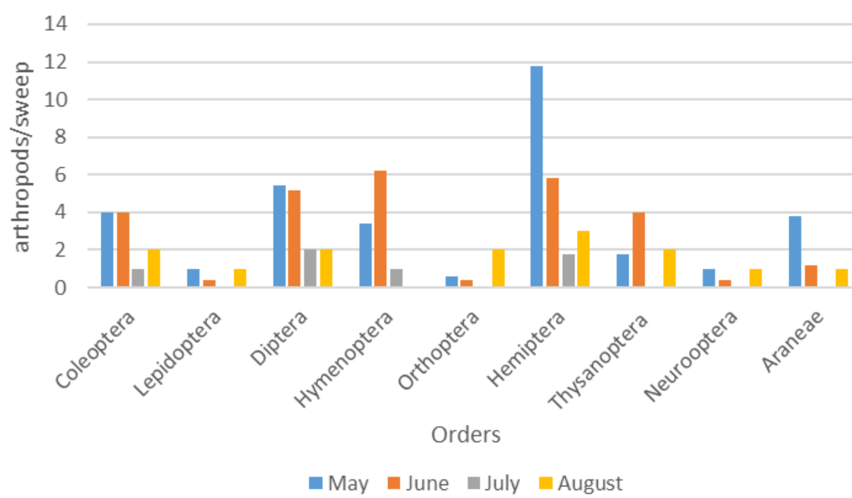

Figure 12. Sweep net arthropod collections, by month, are expressed by average number of spiders (Araneae) and insects by order, for no-till corn and soybean rotations that included the use of cover crops. These data provide a seasonal population response to the cropping system. Eight insect orders were used as a template of insect response.

Arthropod data collected from fields with crop rotation systems using no-till winter wheat and cover crops and from traditional row-crop fields

For the past few decades winter wheat production in Missouri has not been as profitable when included in a corn/soybean rotation, which is one reason many agriculture producers have excluded wheat from their rotations. However, some agriculture producers will plant wheat to generate a mid-season cash flow and then follow with a double crop of soybeans after the wheat harvest. If soil moisture is adequate, this double-crop system works well; however, double-cropped soybeans, usually established in June or July, can suffer from drought. Having wheat in the rotation does impact soil measurements, which positively influences those soil health parameters and the microbial community.

During May and June, sweep net collections were made in winter wheat fields with an average total of 47 insect and spider individuals found compared to 27 insect and spider individuals found within fields in the traditional corn and soybean rotation (Figure 13). However, during July and August, overall numbers dropped similar to the pattern observed with the corn/soybean rotation regardless of if a cover crop was used (Figures 11 and 12).

Information from Figures 11 and 12 provides evidence that fields established with polyculture and pollinator mixtures, CRP fields, tended to provide higher arthropod counts during this same period. These higher numbers were primarily due to the loss of food sources and the lack of diverse habitats within the traditional row-crop fields during late summer. As arthropod diversity decreases, there may be increased opportunities for destructive insects to reduce crop yields, as there are fewer predator insects available to control outbreaks. Establishing a field border or refugia adjacent to crop fields can provide a diversity of vegetation that supports a predator–prey balance, which can serve to potentially reduce damage caused by nonbeneficial crop-damaging, or phytophagous, insects that can reach economic threshold.

Arthropod data collected from fields using no-till winter wheat and cover crops with double-cropped soybeans in the crop rotation system

Another cropping option is to include double-cropped soybeans in the crop rotation system. Figure 14 shows arthropods collected within fields using a double-crop wheat/soybean

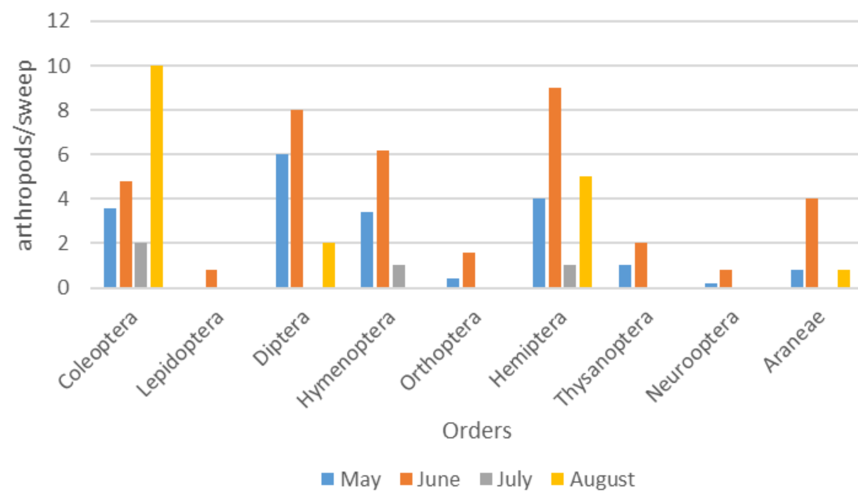

Figure 13. Sweep net arthropod collections for no-till winter wheat providing a seasonal population response (depicted as a monthly average) to the cropping systems. Eight insect orders and spiders (Araneae) were used as a template of the arthropod response.

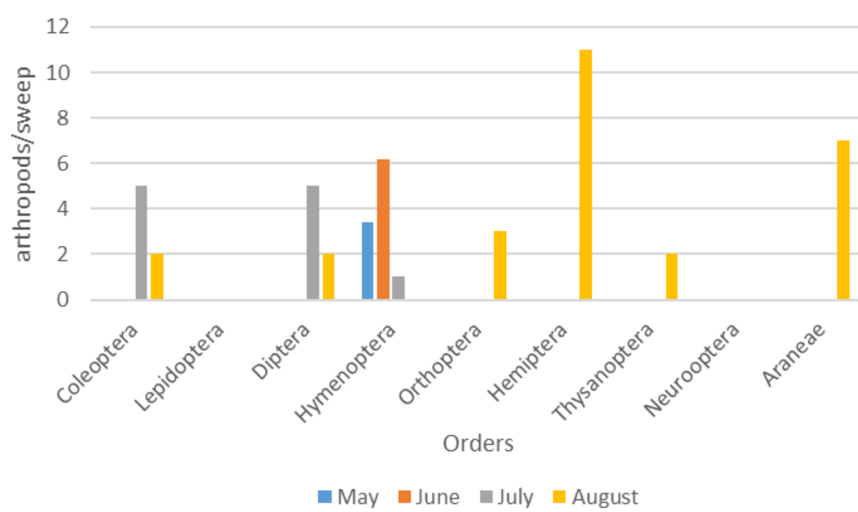

Figure 14. Sweep net collections for double-cropped soybeans providing a seasonal population response (depicted using average numbers of arthropods) to the cropping systems. Eight insect orders and spiders (Araneae) were used as a template of the arthropod response.

rotation, and results indicate that arthropod use differs with most other agricultural systems used. The numbers collected were relatively high: 37 individuals representing eight insect orders and spiders (Araneae). Although this crop rotation system does not provide the same benefits as do the refugia or the CRP fields, there was an increase in insect abundance over other cropping systems during the later summer months of July and August.

If the objective is to maintain a beneficial insect community at an elevated level throughout the summer within a crop rotation system, then the double crop soybeans would be a good option. However, this might not be a cost-effective option with the inherent risk of drought stress to the soybeans. Figure 14 also depicts a drop in the number of insect orders in the collection, a theme that is repeated in each of the crop rotation system treatments that were conducted. However, these numbers are deceptively different due to the narrow timeframe of the insect collection.

Evaluation of the diversity of arthropods, including pollinator insects, in established fields with native forbs and cover crops

When a diversity of vegetation is established and managed — either using cover crops or through native forbs and legumes within a field border or a refugium — within an agricultural landscape in which row crops predominate, we observed that the overall soil health, soil biota and arthropod biota were improved. When plant diversity is increased within established native plantings, the diversity of bees and other insects increases along with those soil health parameters, as previously discussed. Managing row-crop systems that provide benefits to the insect and wildlife community can be important for the long-term productivity of agricultural crops.

To measure the arthropod responses to the native plantings, sweep net data was collected on nine sites every two weeks across several different habitats. Once again, arthropod identification was completed to order level, which provided trend information. Within the order classification, there can be variations of beneficial and nonbeneficial insects, but our focus was on how the orders responded to management, making the trends more presentable.

One of the most important wildlife habitat management tools is prescribed fire. Prescribed fire creates a disturbance that maintains early stages of plant succession, such as with native annual and perennial plants — forbs, legumes, wildflowers and native grasses. Two of our treatments and field sites were developed during a previous year, using a 10-species native plant mix similar to the CRP plantings previously described. One site was managed with a prescribed fire to maintain early stages of succession; the other site was not, thus allowing plant succession to proceed to later stages of growth (Figures 15 and 16).

Summary of arthropod data collected from areas using prescribed fire as a management tool

As mentioned earlier, one of the important reasons to use prescribed fire as a habitat management tool is to promote early successional vegetation, which includes annual seed-producing native species, many of which have adapted to a frequent disturbance such as fire. Data from Figure 15 depict the arthropod collections from a CRP field that also contained a mixture of native pollinator plantings but did not have a prescribed fire used as a management tool. Figure 16 depicts the arthropod data that was collected one year after a controlled burn, so the plant community was still responding from the burn with lush and new growth. The insect community also responded with most of the

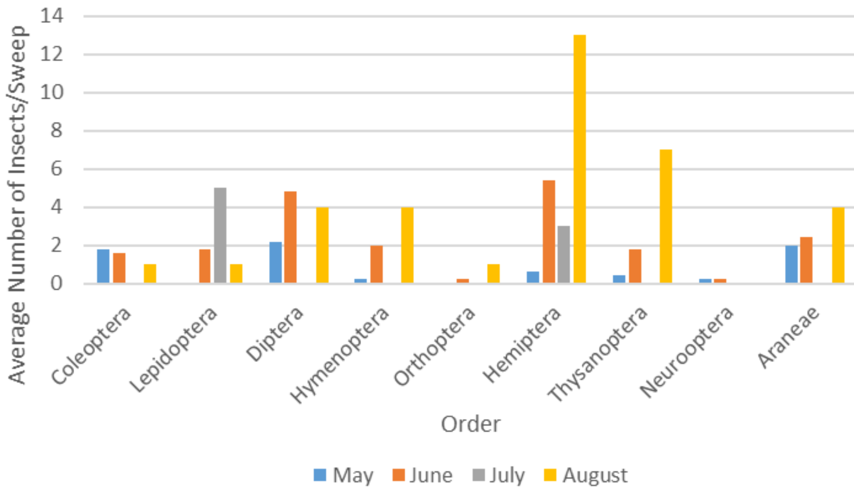

Figure 15. Arthropods collected in native pollinator plantings that did not have a prescribed fire used as a management tool. Eight insect orders and spiders (Araneae) were used a template of arthropod response.

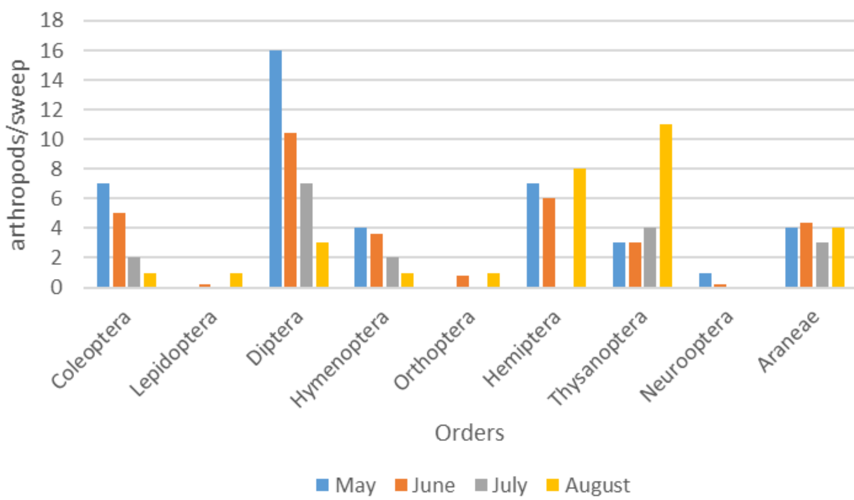

Figure 16. Arthropods collected in native pollinator plantings in which a prescribed fire was used as a management tool. These collections were made one year after the prescribed fire was conducted. Eight insect orders and spiders (Araneae) were used as a template of arthropod response.

However, when a controlled burn was used, all nine arthropod orders were represented, and most were still present through the duration of the sampling season (Figure 16). Within the nonburned areas, we observed that a large number of the orders represented within the collection were not present during the sampling season (Figure 15). The orders of Diptera and Lepidoptera had the greatest response during the year within the nonburned plots and had a similar response within the plots in which a prescribed fire was conducted.

Arthropod collections from fields that were established using a polyculture cover crop mixture in place of the traditional CRP mixture

Adding a grass component to the plant diversity within the field also provided some additional cover for arthropods and spiders during the winter months (Figure 17). These mixtures are commonly recommended by the Missouri Department of Conservation, and thus, we compared these values with similar management techniques but using a polyculture of annual cover crops in the mix rather than native forbs (Figure 18).

orders being represented in the collection each month. Prescribed fire is an important management tool as it helps to create vegetation that provides habitats for a diverse arthropod community as well as for wildlife species that depend on insects for food and on the cover established for nesting and brood-rearing habitat.

Arthropods that are limited by mobility have the greatest challenge reestablishing in new habitats.

There were differences in the number of arthropod orders that were observed between these two treatments. When only native forbs were used, some orders were not represented during each of the sampling periods (Figure 17). However, there were a greater number of orders present in CRP fields that used the polyculture mixtures

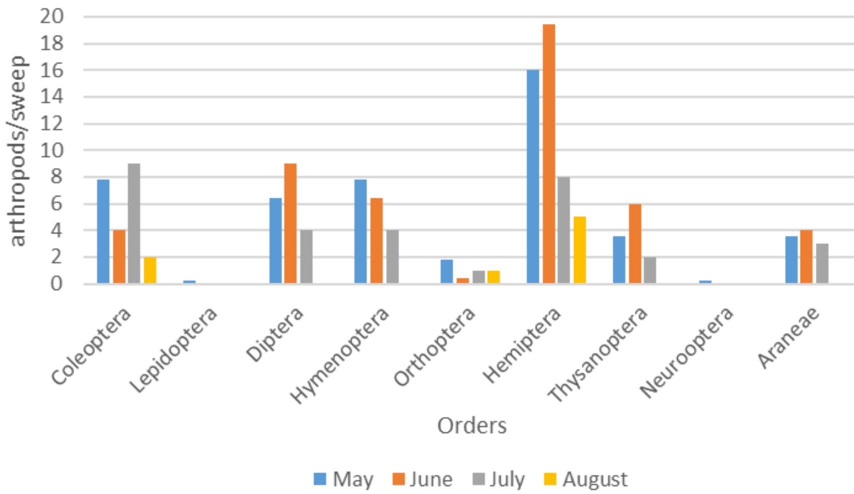

Figure 17. Sweep net arthropod collections for traditional CRP systems which provides a baseline data set of arthropod responses to seasonal influences. Eight insect orders and spiders (Araneae) were used as a template of arthropod response.

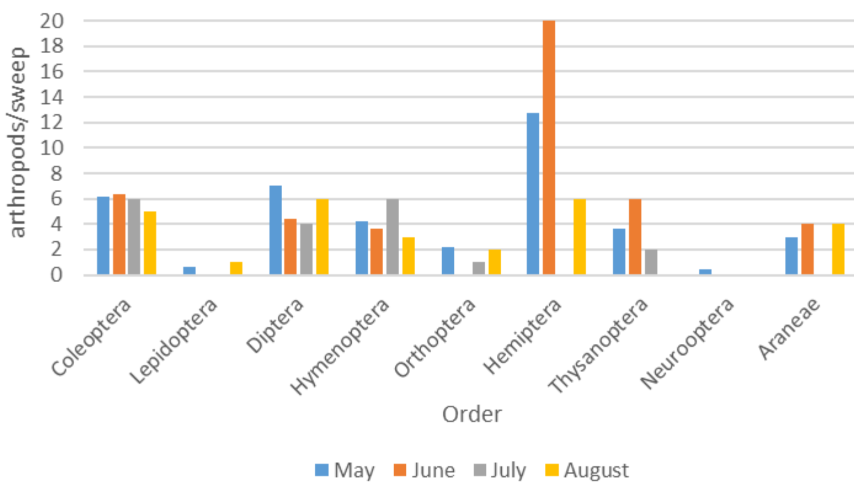

Figure 18. Sweep net arthropod collections comparison documenting response of using annual cover crop plantings to replace traditional CRP systems. Eight insect orders and spiders (Araneae) were used as a template of arthropod response.

(Figure 18). Having a greater number of arthropod orders represented in the collection provides a measure of a sustainable insect community.

Arthropod orders dropping out of the collection was most likely due to the natural progression of plant succession, which creates less plant and influences the quality of habitat. Having a diversity of arthropod orders within each field or treatment may provide an opportunity for the insect community to respond more quickly, particularly if those plantings are located near one another.

To maintain plant diversity, several CRP practices were designed to be implemented so that they were adjacent to crop field edges. Adding cover crops to the row-crop rotation system and allowing them to be established adjacent the crop field edge may also serve as a conservation practice. These annual polyculture cover crops are generally more cost effective to establish than native plantings, but management costs may be greater. Results from this case study indicate that annual polyculture cover crops can be used to provide an effective transition from the row-crop field edge and enhance habitats for arthropods, including beneficial insects, as well as for species of wildlife requiring early plant successional communities for food and cover.

Summary of arthropod data collected from each field treatment during the course of this case study

Figure 19 depicts the total number of arthropods collected using sweep nets within each of the fields (categorized as a treatment) used during this case study. The treatments (T) are described in the previous section as well as in Figure 19. With the focus mainly on using trend information, it was determined that the highest number of arthropod orders were collected from Treatment 3 (T3), the CRP field with a mix of annual cover crop species instead of native plants.

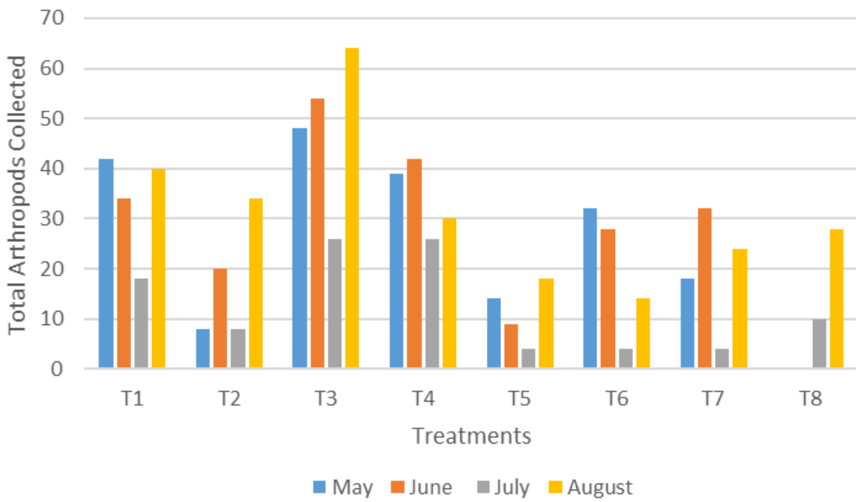

Figure 19. Seasonal arthropod sweep net collection showing seasonal trends across all field treatments. Information presented shows the total number of arthropods collected during each sampling period.

Legend

T1 = Pollinator habitat after controlled burn
T2 = Pollinator habitat nonburned
T3 = CRP with five species annual cover crops
T4 = Traditional CRP with 10 native species mix
T5 = Conventional corn and soybean rotation
T6 = No-till corn and soybean rotation with cover crops
T7 = No-till wheat with broadcasted cover crops
T8 = No-till wheat

A more thorough understanding of how cover crops help build soil biota and improve overall soil health is important. However, it is also important to understand how a cover crop will affect the aboveground arthropod community, including beneficial insects, as well as the wildlife community. With the information gained from this case study, we were able to determine that, although agriculture field systems do not support the same numbers of arthropods as those designed with conservation objectives, they can play an important role in maintaining these populations. With the use of cover crops in a row-crop rotation system, we have demonstrated that a diversity of arthropods — insects and spiders — use these systems until late in the summer and then move to the field edges, most likely as a response to the greater diversity of vegetation and the food sources that are available within the refugia and field border habitats.

Treatment 1 (T1), in which a prescribed fire was conducted within the native planting plot, also had high numbers of arthropods. Each of these treatments contained newly emerging vegetation that continued to grow throughout the season. Treatment 4 (T4) was the traditional CRP planting, which also supports a stable and relatively abundant and diverse arthropod community.

When reviewing the cropping systems, treatments 5 through 8 (T5 to T8), we observed that the numbers of arthropods declined throughout the summer months, but especially during July. However, the total numbers of arthropods found within the cropping system increased in Treatment 6 (T6), which included a five-species annual cover crop polyculture within the established CRP field.

Comparison of optimal bloom windows provided by ecotype-specific native plantings

As part of a previous project, we investigated various planting options that potentially provided enhanced habitat for insects that serve as pollinators and were thus able to make comparisons with the plantings established during this case study. Information obtained demonstrated that arthropod populations benefit from habitats that are available through the late summer months and that native plants can provide nectar sources throughout the summer. Plants for this demonstration were chosen based on their different bloom times during various stages

Table 6. Native plant presence–absence chart and their bloom-time for the pollinator ecotype planting.[1]

Species planted	Late May to Mid-June			Mid-June to mid-July			Mid-July to mid-August		
	Missouri	Adjacent	Outer	Missouri	Adjacent	Outer	Missouri	Adjacent	Outer
Blackeyed Susan	1	4	1	17	25	23	2	7	1
Partridge pea	0	0	0	4	1	1	0	0	1
Sunflower ox-eye	7	3	1	0	5	6	1	7	2
Pale purple coneflower	0	2	1	1	0	0	0	0	0
Foxglove beardtongue	18	12	9	30	27	33	5	6	1
Prairie blazing star	1	0	0	1	1	0	0	0	0
Stiff goldenrod	1	2	1	12	8	3	0	0	1
Blue vervain	1	1	1	0	0	0	3	1	0
Plains coreopsis	0	0	0	3	0	0	0	0	0
Purple prairie clover	0	0	0	0	0	0	0	0	0
Total	29	24	14	68	67	66	11	21	6

1. The 10 native species used were based on information provided by the Missouri Department of Conservation.

of the season — creating a longer window for nectar sources (Table 6). Plots were established to compare plants from Missouri ecotype sources with sources found in adjacent states, including from Kansas and Illinois, and from sources from the nonadjoining states of Texas and Minnesota.

Foxglove beardtongue, blackeyed Susan, and sunflower ox-eye dominated the planting (Table 6). In early summer, the Missouri and adjacent ecotype plots contained more plants than those from the outer ecotype. However, in each of the plots, six of the 10 species were present. By midseason, foxglove beardtongue still had a strong presence, but species from the outer ecotype exhibited a greater presence than they did during the earlier timeframe. The bloom-time lag from those species from the outer ecotype indicated that these native species are daylength sensitive, which can be problematic if they are grown out of their natural areas because some insect species may depend on a specific flowering period for nectar sources.

Mixing ecotype seed sources can prolong the bloom window, which is an important factor when choosing plants for insect pollinator benefits. It is important to understand the flowering trends of various species and to establish refugia with plants that have varying bloom windows to provide nectar for pollinators and beneficial insects for a longer period of time.

Methods used to assess wildlife habitat during the case study

In addition to collecting information on how cover crops and establishment of refugia and field borders affected soil health parameters and arthropod diversity from the use of various field treatments, we were able to use a selection of habitat evaluation tools to assess the quality of habitat that existed in the various locations in which this case study was conducted. Wildlife habitat indexes, or models, are tools used by wildlife biologists and landowners to determine if a particular area provides habitat that is suitable for sustaining certain populations of wildlife. These models have been developed to evaluate the habitat attributes required by certain wildlife species and as a tool to evaluate and assess the attributes of a particular community of vegetation for supplying habitat for a diversity of wildlife species. Each model allows the user to evaluate the quality of the habitat in an area in its current condition. The user can then use a scoring system that provides a process for rating the habitat in that same area that would be created if certain management practices were conducted at some point in the future.

For instance, there are habitat assessment models developed to rate the plant community conditions specifically for grassland birds, wild turkey, white-tailed deer, bobwhite quail or a diversity or community of wildlife species. These models have also been created to rate the habitat that currently exists on the ground for designated field conditions or uses, such as for croplands or woodlands. Important habitat components that are required for a species are identified, and these can be evaluated on the property to determine if the area provides suitable habitat. If it is found that certain habitat components are not available, or are limiting, actions can be taken to manage the area to address the components in short supply.

For this case study, we used the following ecological sciences tools, or wildlife habitat assessment guides, to evaluate the condition of the areas, fields and overall plant community in which cover crops, field border practices and refugia, and various field treatments were implemented:

- Missouri Wildlife Habitat Appraisal Guide: Cropland Community Model (PDF)[3]
- Missouri Wildlife Habitat Appraisal Guide: Early Successional Vegetation Community Model (PDF)[4]
- Missouri Bobwhite Quail Habitat Appraisal Guide[5] (MU Extension publication MP902)

As discussed, each of these habitat assessment guides identifies important attributes that contribute to the value of a particular field or area for providing habitat for a community of wildlife or for certain species of interest. They each consist of a rating system that provides a numerical value that represents the quality of the existing habitat condition and rates specific components, both within a field and in the surrounding area, at a specific point in time. The ratings can be improved as habitat practices are conducted that address the limiting factors that have been identified.

The Cropland Community Model

The Cropland Community Model uses various categories to evaluate the quality of the crop field for wildlife habitat:

- Presence of a field border or edge
- Crop field management techniques that are implemented
- Food value of residues or grain strip
- Size of the field
- The existence of shrubby escape cover in the area

Traditional indexes usually rate crop fields as being of only marginal value. However, during this case study, crop fields were viewed as potentially providing important seasonal habitats, and with the implementation of cover crops, we would expect that their value for habitat would increase, given the longer period that food and cover would be available during the year. The focus of using the Cropland Community Model during this project was to create a habitat index that rated the quantity and quality of habitat within the crop field and the surrounding area and that of the crop field with and without a cover crop as part of the rotation. The five main criteria used for rating croplands within this model are wildlife friendly field borders, crop field management, food value, crop rotation, and field size and shrubby cover.

Wildlife friendly field borders. This criteria carries the greatest weight as habitat values are ranked. Field borders must be a minimum width of 30 feet. For existing borders or filter strips to qualify as wildlife friendly, 60% of the canopy must be dominated by herbaceous vegetation having a good or excellent wildlife rating. Existing borders containing more than 40% herbaceous vegetation rate poor, and those with more than 10% undesirable species — sericea lespedeza, reed canarygrass, musk thistle, Canada thistle, spotted knapweed or teasel — or dominated by tree canopy coverage score zero points. A border comprised of a wildlife-friendly mix around the entire field scores zero points if it is mowed April 1 through July 15.

Crop field management. This criteria also carries a heavily weighted value. The amount of crop residue is an important factor in rating the value of this criteria. Fall tillage greatly reduces the overall values. Residue is important in the spring and summer as well as over winter. In general, any use or disturbance of the residues will result in a lower score. For example, a field with fall tillage — disked with residues reduced to 40% — would score 5 points. That same field with residues reduced to 20% or burned in the fall would score 3 points — recognizing the decline in habitat quality.

Food value. Food plots or unharvested grain strips must be a minimum of 30 feet wide. Fields larger than 80 acres require the food plot or unharvested grain to be left in two or more separate locations. For example, a 100-acre field does not get credit if the unharvested grain is concentrated in one corner. These areas must remain through the winter until March 31 of the following year and should be adjacent to quality escape cover such as shrubby thickets. To score the highest rating, the field should have a minimum of a half acre of unharvested grain in a 50-acre crop field — a quarter acre for each 1 to 40 acres.

Crop rotation. To score the highest rating, rotations should include at least three different crops, with small grains or winter cover crop at least one out of four years. Small grains are defined as oats, wheat, rye or barley.

Field size and shrubby cover. The amount of a field within 660 feet of dense shrubby cover is an important factor. Dense woody cover is defined as ungrazed shrubs, 3-to-12-foot-tall dense shrub thickets, edge-feathered field edges or downed tree structures. The minimum area that qualifies is 30 feet by 50 feet. Shrubby cover must be ungrazed, lack a dense grassy understory, and be free of sod-forming grasses to be counted for this category — for example, a dense dogwood thicket surrounded by tall fescue would not be considered usable shrubby cover.

A maximum potential score of 45 can be obtained for criteria rated with this model. Refer to the Missouri Wildlife Habitat Appraisal Guide: Cropland Community Model (PDF)[3] for instructions and a score sheet.

The Early Successional Vegetation Community Model

The Early Successional Vegetation Community Model was developed for evaluating the benefits of idle areas, old fields or other locations in which annual and perennial grasses and forbs and shrubby cover are available within the area. Specific categories of importance include the amount and quality of shrubby cover, composition of the grasslands or pastures in the area, the amount and diversity of native forbs and legumes, and the frequency that management practices, such as disturbance regimes, are conducted.

Shrubby cover quantity and quality. This criterion carries the greatest weight within the model. The greater the percentage of the crop field that is within 150 feet of usable shrubby cover, the higher the ranking. Any shrubby cover with sod-forming fescue or brome underneath is unusable space for wildlife. Usable shrubby cover may consist of shrub thickets, briar patches, edge-feathered woodlands, and/or downed tree structures that are 3 to 12 feet in height with bare ground underneath and at least 1,500 square feet in area.

Grassland composition. This criterion also carries a great amount of weight within the model. For a maximum point rating, a mixed native grass, forb and legume grassland contains at least two native grass species. Desirable forbs and/or legumes should comprise 10% to 75% of the canopy coverage. For example, a native grass monoculture would score only 2 points. To qualify as wildlife friendly, 60% of the mixture should be dominated by species having a good or excellent wildlife rating; species that qualify are found on the scoresheet.

Desirable forb and legume diversity. This is another important criterion for ranking the value of early successional vegetation. Desirable forbs include legumes, native prairie forbs and most broad-leaved plants, or "weeds," such as ragweed. Refer to the common quail foods listed in MU Extension publication MP902, Missouri Bobwhite Quail Habitat Appraisal Guide.[5] It takes a very diverse grassland to exceed 20 species of forbs within a field. Nonnative legumes and forbs would not be considered beneficial in a native prairie — for example, sweet clover or birds foot trefoil in a native prairie or other natural community — whereas they could be considered desirable in a planted pasture or hayfield.

Desirable forb and legume canopy coverage. Estimate the percentage of the soil surface that is shaded by desirable forbs. A square meter plot can be used from overhead, and the percentage of the plot covered by desirable broad-leaved plants can be estimated.

Vegetative cover. The percentage of herbaceous vegetation in the entire field that is greater than 8 inches tall can be evaluated based on how it appears between May 15 and Sept. 15. Dense, rank grass or herbaceous vegetation, such as unmanaged fescue, would score zero points.

Periodic management. Periodic disturbance is an important consideration, and 10 points are given if the disturbance is conducted on a frequent basis, such as every one to three years. The area being evaluated is not conducive for early successional habitat if the disturbance cycle is longer than five years.

A maximum potential score of 65 can be obtained for criteria rated with this model. Refer to Missouri Wildlife Habitat Appraisal Guide: Early Successional Vegetation Community Model (PDF)[4] the for instructions and a score sheet.

The Bobwhite Quail Habitat Appraisal Tool

The Bobwhite Quail Habitat Appraisal Tool is designed for the user to evaluate areas of property to determine the availability of important habitat components necessary for bobwhite quail nesting and brood-rearing cover and for escape cover for use throughout the year. The user can designate certain areas on the property for focusing management efforts, such as a typical area of land required for a covey home range, for example, 40 to 50 acres. The quantity and quality of these cover types on the property as well as the availability of food items are important aspects of the evaluation. Each of these criteria carry an equal weight in terms of ranking their importance within the context of the evaluation tool.

Important habitat components that are evaluated within an area are nesting cover, brood-rearing cover, escape cover / covey headquarters, food, and arrangement of cover types.

Nesting cover. Nesting cover typically consists of grasses at least 12 inches in height to conceal quail. Small clumps of grass with last year's grass residue are preferred. Nesting cover should be open clumps of grass that can conceal the nest site with open ground available to allow chick movement after hatching. Grasses must also be near brood-rearing habitat.

Brood-rearing cover. Brood rearing cover is characterized by a plant community made up of legumes and annual weeds. These habitats are typically found in areas that have been left fallow one to two years after a soil disturbance. Open conditions at the soil surface are crucial for optimal brood rearing habitat. At least 25% to 50% of the area should consist of bare ground.

Escape cover / covey headquarters. Protective or escape cover is used by bobwhites throughout the year and is necessary for eluding predators. Stands of overgrown shrubby cover as well as stands of grass and weedy areas open at ground level are typically used. Protective cover must persist throughout the year, especially during cold weather when thermal protection is needed, and during the summer for protection from heat and sun. The lack of escape cover is often identified as a limiting factor on many farms in Missouri. Escape cover should be available in patches that are at least 30 feet by 50 feet. It is also extremely important that food sources be available adjacent to protective cover. These areas are also referred to as covey headquarters. A covey headquarters area consists of patches of woody shrubs that provide overhead cover and open access at ground level.

Food. The diet of adult bobwhite quail consists of insects, seeds and fruits of annual weeds, legumes, grasses, shrubs, trees and cultivated crops. Seeds are eaten throughout the year but are heavily used during the fall and winter. Insects are high in protein and are eaten during the spring, summer and fall. Insects are a particularly important food sources for young chicks during the summer.

Arrangement of cover types. Bobwhites are an edge species that require a mix of grasses and herbaceous cover, agricultural crops and brushy cover all closely arranged together.

A maximum potential score of 140 can be obtained for criteria rated with the Bobwhite Quail Habitat Appraisal Tool. For more information on using this tool to assess your land's potential for bobwhites, refer to MU Extension publication MP902, Missouri Bobwhite Quail Habitat Appraisal Guide.[5]

Habitat index ratings resulting from various cropland field treatments

The information in Table 7 provides habitat ratings from using the Cropland Community Model, the Early Successional Vegetation Community Model and the Bobwhite Quail Habitat Appraisal Tool as assessments were conducted on cropland field treatments that included the use of cover crop rotations as part of the management system. Assessments were conducted during summer months. Values were obtained by rating the habitat criteria that each model identified, both within the various field treatments as well as the surrounding area. Habitat index values were collected for each treatment by rating criteria within each of the models separately and then obtaining a combined habitat index value for each appraisal method.

The lower habitat rating scores as determined by the Cropland Community Model can primarily be attributed to the absence of a quality field border around the wheat cover crop CRP field and the traditional crop fields. A lack of shrubby cover was a primary reason for lower habitat ratings as determined by the Early Successional Vegetation Community Model for the two traditional crop fields and the wheat cover crop CRP field. In most circumstances, it would be assumed that the traditional CRP field would have had a higher habitat index value than the cover crop CRP when using the cropland and early successional vegetation community models; however, the overall ratings depend on multiple factors, including field size, presence of a field border and plant diversity within the fields. Also, a traditional CRP planting that was established using a perennial grass will often take two years to become established as opposed to a single year for a traditional crop field. As the case study continued, the habitat index values were switched with the addition of the cover crop within both fields, which provided higher index values than those observed within the traditional cropping system.

Habitat ratings were higher for the cover crop CRP and Boone County traditional CRP fields as determined by the Bobwhite Quail Habitat Appraisal Tool, primarily due to availability of nesting and brood-rearing habitat that was observed in those fields as well as the shrubby escape cover that existed. The winter wheat cover crop field also had a relatively high habitat index value, primarily due to the quick emergence of the cover crops, which provided nesting and brood-rearing cover. Fields that had cover crops established as a rotation had higher habitat indexes as compared with the two traditional CRP fields that were primarily composed of a monoculture of a perennial cool season grass.

The primary difference in the habitat quality measures between the two traditional CRP fields was primarily due to the fact that one of the fields had excellent weed control and the diversity of weed species was very low, which negatively affects the availability of food and cover. The traditional crop fields were located within

Table 7. Habitat quality indexes calculated from the crop fields evaluated using three appraisal methods.

Habitat appraisal method	Wheat cover crop CRP	Cover crop CRP	Boone County traditional CRP	Boone County traditional crop field	Callaway County traditional crop field
Cropland Community Model	12/45	23/45	20/45	11/45	5/45
Early Successional Vegetation Community Model	30/65	54/65	43/65	13/65	17/65
Bobwhite Quail Habitat Appraisal Tool	95/140	123/140	112/140	17/140	49/140

landscapes that had little vegetative diversity, which lowered habitat ratings due to an absence of field borders around each field.

Tillage operations also play an important role as the indexes are calculated. If the farming operation uses no-till, residue is left that provides a food resource and enhances the opportunities for use as nesting habitat. If all the residual residue is tilled, this habitat component is no longer available and lack of food and cover becomes a limiting factor.

Table 8 depicts the habitat index values that were obtained from crop fields at two Missouri Department of Conservation areas in southwest Missouri and from crop fields of private landowners in Cooper and Barton counties. Each of these areas was used as a comparison during the case study.

The attributes that are considered from each of the models, as previously described, were subjectively evaluated at each location during the summer, and an overall habitat index value was calculated and used for a comparison. Once again, the presence of field borders and quality shrubby cover, which carry the greatest influence within the cropland and early successional vegetation community models, was one of the reasons for the higher habitat ratings found at the Seat Memorial Conservation Area and Cooper County cooperator fields. Ratings for the habitat attributes evaluated by the Early Successional Vegetation Community Model and Bobwhite Quail Habitat Appraisal Tool were more closely aligned with each of the four locations during the period that the evaluations were conducted.

One of the objectives of using these habitat assessment tools and community models as a part of this case study was to demonstrate how they could each be used by landowners to evaluate the existing condition of row-crop fields and surrounding areas for potential wildlife habitat. Each tool allows the landowner to rate the existing conditions and observe how planned activities to be implemented can improve the overall habitat index value if conducted during ongoing farm management activities.

Conducting economic analyses of integrating cover crops in crop production situations

Specific economic information on use of cover crops was not collected during this case study. This section highlights useful information that can be easily collected to evaluate the financial impact of cover crops on an individual farm or field. The economic benefits of a particular crop

Table 8. Wildlife habitat indexes obtained from fields across Missouri using three appraisal methods.

Habitat appraisal method	Shawnee Trail Conversation Area (Southwest MO)	Seat Memorial Conservation Area (North Central MO)	Cooper County cooperator (Central MO)	Barton County cooperator (Southwest MO)
Cropland Community Model	23/45	30/45	30/45	28/45
Early Successional Vegetation Community Model	31/65	31/65	31/65	35/65
Bobwhite Quail Habitat Appraisal Tool	97/140	104/140	102/140	93/140

production system are typically assessed each year with an expectation that benefits accrue over time. Collection of input costs, yield data and any changes in field activities undertaken due to the cover crop is necessary for a thorough analysis.

Cover crops have not been reliably proven to immediately increase crop yield after adoption. Cover crops can increase soil organic matter, water holding capacity, oxygenation, microbial activity and nutrient availability. Each of these environmental benefits can increase crop yield depending on a variety of factors, but the effects take time to be realized. Because cover crops provide many of their economic and conservation benefits in the years after initial adoption, much of the benefit of the cover crop is realized by future crops. Planting cover crops in the rotation can affect input costs for pest management and fertility. They can also impact wildlife habitat and soil erosion control costs — costs that are more difficult to assign economic value.

It is important for an economic analysis to be conducted in various stages over enough time for all potential effects of the cover crop to take affect. Incorporate changes in annual direct production costs and yield into yearly enterprise budgets. As years progress, converting the annual costs and benefits of this period up to the present estimates the long-term value of the cover crop.

The types of information needed for conducting these various types of analyses are described below.

Collecting direct costs of production in cropping systems

The information needed for this type of analysis includes the variable input costs and an estimate of the costs of equipment in establishing and managing cover crops. Typical costs include establishment and maintenance costs for seed purchases, fertility inputs and machinery costs. Closely monitor and record the production costs associated with the row crop being grown as well. Many of the potential economic benefits from cover crops are realized by input savings in the cash crop. Ideally, detailed budgets for row crops grown both with and without cover crops should be recorded for the duration of the study to compare returns to cropping systems with and without the inclusion of cover crops.

Conducting a multiyear total-system benefit analysis

The benefits of using cover crops in row-crop production systems are typically realized during successive years, and ecological benefits accumulate over multiple growing seasons. To assess the viability of establishing a cover crop, all benefits must be documented. For example, research has documented that it takes about four years before significant changes in soil health indicators and soil fertility measures are observed when using an annual cover crop. However, significant responses to these parameters can be observed in two years when a perennial cover crop, such as red clover, is established.

Specific cross comparisons of various cover crop decisions provide useful insights. For example, compare the use of cover crops to planting soybeans after wheat, compare cover crops following soybeans to those following corn, or compare the companion benefits of cover crops adjoining crops in a field border. A particularly interesting comparison could be evaluating the benefits of seeding the area with specific cover crop ecotypes rather than varieties bred for other regions.

Conversion of multiseason benefits and costs back to a single season

When evaluating the long-term impact of cover crops, it's helpful to convert multiyear costs and benefits into a single season for easier comparison. To do this, you adjust past costs or benefits to today's dollars using inflation. Previous year's values would be brought to the present by multiplying each of those values by an inflation adjustment: Present value = Past value × (1 + inflation rate)^n, with ***n*** being the number of years since those values were incurred. For example, if you spent $25 per acre on cover crops last year and inflation was 4%, that cost today would be $26 per acre, or $25 × 1.04. If your benefit this year is $30 per acre, then your net gain over the two years is $4 per acre, or $30 benefit minus $26 adjusted cost. You can repeat this process each year to track how cover crops are paying off over time. This information helps you make better decisions about whether the long-term investment is worth it.

For more information on the economics of establishing and managing cover crops and for more details on production costs and benefits, refer to Cover Crop Economics.[6]

Case study overview and summary

How did the use of cover crops influence soil health, pollinators, and wildlife habitat?

Results of this study indicated that many of the basic agronomic principles that lead to better soil health — such as using a greater diversity of crops, using crop rotation systems, reducing tillage applications, and using mixtures of native grasses and forbs/legumes and other native plants — also provided important habitats for beneficial insects and a suite of pollinators as well as a variety of wildlife species.

Cover cropping systems

How are cover crops managed?

Cover crops are usually planted after the cash crop (corn or soybeans are the predominant row crops in Missouri) is harvested during the fall. These cover crops can be legumes, brassicas or cereal crops. Some cover crop species, such as radish and other brassicas, will winter kill, whereas others will survive the winter and begin growth in the spring. Annual winter cover crops are terminated in the spring before the cash crop is planted. Cover crops that include legumes can be advantageous as the legume component can add nitrogen through biological fixation. In addition, cover crops can improve soil and water conservation and enhance wildlife and pollinator habitat if properly managed. During this case study, a combination of cover crop systems using monocultures and polycultures were established and managed using traditional agronomic techniques as described in the methodology section.

Can cover crops provide other benefits?

Yes, during the case study, winter annual cover crops helped reduce certain herbicide-resistant weeds — such as giant ragweed, marestail and water hemp, which emerge in the early spring — through competition and by blocking out the sunlight required for seeds to germinate (Figure 20).

What are the advantages to mixed cover crops, or polyculture, stands?

A mixed stand of cover crops that includes cereals, legumes and brassicas — often referred to as a polyculture system — resulted in a greater diversity of soil microorganisms, attracting a wider range of beneficial insects and offering more soil protection during the winter (Figure 21).

Figure 20. (a) Soybeans following a cover crop compared to (b) no cover crop control. Early spring germinating weeds, such as giant ragweed and marestail, are reduced when cereal rye is planted.

What does it mean to plant into a green cover crop?

Planting into a green cover crop means that the cover crop is not terminated before the cash crop is planted: The cash crop is planted directly into the standing cover crop (Figure 22). Afterward, the cover crop can be terminated. When establishing soybeans at average planting dates in Missouri, the cereal and legume cover crops are near their maximum dry matter production, whereas at the time of planting corn, earlier in the spring, cover crops are still growing. Delaying termination of cover crops provides a longer time for them to be used by insect pollinators and other arthropods.

Figure 21. A mixture of cover crops — including cereal rye, crimson clover, Austrian winter pea and hairy vetch — provides a diversity of plants that add beneficial services as opposed to planting a single cover crop or monoculture.

Figure 22. The practice of planting a cash crop, such as corn or soybeans, directly into a cover crop is referred to as planting into a green cover crop.

Are there any issues when planting into a green cover crop?

A key to planting into a green cover crop is to procure good seed-to-soil contact. To accomplish good contact, take the time to maximize planter performance (Figure 23a). Another potential issue is the slower emergence of the corn and soybean plant that is established into an existing cover crop, which could be due to a lack of moisture as well as competition for other resources. This slower emergence is especially a problem with corn as some yield factors are influenced when the corn plant is in the early vegetative stages (Figure 23b).

Figure 23. (a) Good soil to seed contact is crucial when planting into a standing green cover crop; care should be taken to correctly set the planter for these conditions. (b) Due to the tie up of nitrogen and possible water stress, this corn planted into a green cover crop (left) is growing slower than corn planted into a control plot (right).

Does a yield advantage result from cover crops?

Following cover crops, soybean yield is consistently three to seven bushels per acre greater, or about a 10% increase, regardless of whether the cover crop is a cereal or legume planted alone or if using a polyculture mixture (Table 9a). However, corn yield following cereal cover crops can be reduced by 25% or more in some years (Table 9b). This reduction is primarily due to the early stress and nitrogen tie up by the cereal crop. However, when a legume, such as hairy vetch, is mixed with the cereal crop, the corn yield is like that of the areas used as a control. By the fourth year of using cover crops, soil health parameters have improved to the point that there is no longer a corn yield drag but consistent corn yield improvement.

Can summer annual and perennial cover crops be overseeded into wheat?

Yes, but care must be taken not to apply too much nitrogen fertilizer or the cover crops will be smothered out by the stand of wheat.

Are cover crops economical?

When all expenses are considered, there is a direct economic benefit of establishing cover crops before the soybean crop. The increase in soybean yield more than pays for the cost of cover crop seed and establishment. With corn production, however, there is not an economic return, at least in the short run. Terminating the cover crop earlier in the spring may be best so that reduced corn yields do not occur. However, long-term economic benefits from reduced soil erosion and increased water infiltration and retention must be considered. Other economic benefits from cover crops such as improved weed control must also be considered because it could result in a decrease in the amount of herbicides that are applied.

Attributes of soil health

What is soil health?

There are many definitions for soil health, but basically it can be defined as the combination and interaction of soil chemical, biological and physical properties that result in changes to the overall function of the soil and plant that is being grown. These three soil properties are interactive and can influence each other. For example, improved soil chemical, or nutrition, properties and soil biological properties can improve soil physical properties, resulting in better aggregate stability, or soil structure. Aggregate stability improves soil aeration, water availability and infiltration. These improved physical soil properties, in turn, improve soil biological and chemical properties. Plant growth and yield — whether a grain crop, a fiber crop or a forage crop — improves from these interactions.

Do cover crops impact soil health?

Yes, surprisingly, after only two years of establishing a crop rotation using cover crops, soil health values such as total microorganisms and water aggregate stability (WAS) significantly improve. Other soil health attributes such as total soil organic carbon, active carbon and total nitrogen increase after five years of using cover crops (Table 10).

How does soil health compare when cover crops are established in a row-crop rotation with soil health parameters typically found in a restored prairie?

Interestingly, within the top 6 inches of the soil profile in fields that used cover crops over a few years, soil health values were improved to values that are similar those found within a restored prairie ecosystem. However, at deeper depths, restored prairies had better soil health values. This difference is primarily due to the extensive, deep root systems of native perennial plants, which increase organic matter and enhance microbial activity, resulting in better soil physical properties, such as aggregate stability, at deeper depths.

Table 9a. Soybean and cover crop yield based on cover crop used.

Cover crop	Soybean yield (bushels/acre)	Cover crop yield (pounds/acre)
Control	36	—
Hairy vetch (HV)	45	3,095
Crimson clover (CC)	38	523
Austrian winter pea (AWP)	39	3,436
Cereal rye (CR)	42	3,276
HV+CR	50	4,258
CC+CR	47	3,649
AWP+CR	47	3,404
Triticale	38	3,557
HV+CC+AWP+CR	39	5,347

Table 9b. Corn and cover crop yield based on cover crop used.

Cover crop	Corn yield (bushels/acre)	Cover crop yield (pounds/acre)
Control	196	—
Hairy vetch (HV)	210	2,966
Crimson clover (CC)	197	682
Radish	202	992
Triticale	182	1,302
HV+Triticale	207	3,927
CC+Triticale	176	1,654
Radish+Tritcale	194	1,654
Spring oats	201	950
Winter oats	198	1,088
Cereal rye	168	1,249
HV+CC+AWP+Triticale	198	1,250

Table 10. Total soil microorganisms and water aggregate stability after two years treated with or without a cover crop under selected fertilizer treatments.

Treatment	Cover crop	Total soil microorganisms (picomoles/gram)	Water aggregate stability (percent)
No P, K and S fertilizer	No	103,374	15
	Yes	118,922	23
Complete fertilizer	No	109,809	21
	Yes	124,127	28

How does livestock affect soil health on restored prairies?

Soil health on restored prairies can be improved quickly because of the presence of a diversity of plants with different life cycles. Also, rooting depths and types — tap root vs. fibrous — of prairie plant species vary considerably, contributing to improvement in soil health values.

When cattle are grazed on restored prairies, soil health factors, such as the physical property of aggregate stability, are reduced. The reduction of WAS results from hoof compaction during wet periods. However, overall soil health is still greater than when the pasture is predominantly nonnative cool-season grass, such as tall fescue. As in nonnative pastures, care should be taken to pull animals off during wet periods to avoid unnecessary compaction.

Does the MLRA in Missouri make a difference in the soil response to cover crops and other treatments and to attributes affecting soil health?

Yes, Missouri contains many different soil types ranging from deep loess hills to alluvial soils along the Missouri and Mississippi rivers to the Ozarks hills and prairies. The inherent soil productivity of many of these soils, such as sandy soils, is not great and the benefits from cover crops are not as dramatic as those observed in former tallgrass prairie regions and can quickly diminish if soil-health-building factors are not retained.

What is the economic value of improving soil health?

Better soil health leads to more efficient water infiltration and water holding capacity as indicated by the increase in aggregate stability. This effects are especially important during dry years when soil moisture is in short supply and lead to greater economic return. This was demonstrated when soybean yield increased seven bushels per acre during a dry year following cover crops in the rotation. Soybean yield increase was greater during drier years than during a wet year, when yield was three bushels per acre. As soil health improves, soil nitrogen levels increase. This increase provides a source of nitrogen for the cash crop and reduces the need for commercial fertilizer applications.

Cover crops and impacts to beneficial insect, pollinator and arthropod diversity

The decline in insect pollinator populations and the habitats that support them should be a cause for great concern due their importance to our food supply. Pollinators are as important to the success of our food supply as is the quality and health of the soil that supports the crop production system. Cover crops can provide very important habitats for pollinators and wildlife. For more details, refer to MU Extension publication G9499, Establishing and Managing Cover Crops in Missouri for Wildlife and Pollinator Benefits.[7]

Fortunately, as agriculture producers are focusing on soil health, they are also improving pollinator habitat with the use of cover crops. During this case study, arthropod collections were made, looking at the impact different cropping rotations, cropping systems and other field treatments had on arthropod diversity as well as investigating the effects the establishment of refugia and field border habitats had on arthropods and those areas' potential benefit for insect pollinators.

How do crop rotations and establishment of a diversity of vegetation around crop fields affect arthropod diversity?

Crop rotations and the use of cover cropping systems provided very important habitats that positively affected a diversity of arthropods. A very important consideration in using cover crops and managing habitats for insect pollinators is to consider those predator–prey relationships that exist in diverse plant communities that are also promoted in cover cropping systems. For example, aphids can cause damage to row crops through direct feeding and disease transmission, but they are preyed upon by lady beetles. A balanced insect predator–prey population is one indicator of a healthy ecosystem.

We found that there was a lack of arthropod diversity in a traditional corn/soybean rotation, but that when winter wheat was added to the rotation, the number of insect orders increased dramatically. This increase in overall diversity resulted in a larger ratio of predator to prey species. Having fewer insect orders represented in the ecosystem can result in severe crop damage from an outbreak of a pest due to lower numbers of predators, which is indicative of a lower predator–prey ratio.

Including winter wheat in the rotation increases the amount of time that actively growing plants are present within a field —October through April, as compared with corn and soybeans, which are in the field April through September. This increased presence of actively growing plants increases the number of insect orders that are present and improves the predator–prey balance in the field for a longer part of year. The number of insect orders can be further increased by planting summer cover crops after winter wheat harvest. Planting a diversity of summer cover crops can also lengthen the flowering, or bloom, times of various species, further enhancing their value for pollinators.

Do winter annual cover crops attract pollinators and other beneficial insects?

Yes, annual legume cover crops such as crimson clover, hairy vetch and Austrian winter pea attract a wide assortment of pollinator species, including

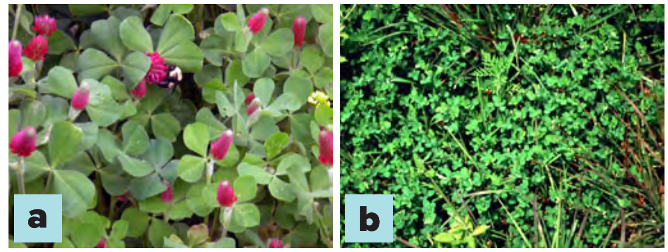

Figure 24. Legumes such as crimson clover (a), annual lespedeza and partridge pea (b) provide good nectar sources for a variety of pollinators, including queen bumble bees, in midspring before many natives begin to bloom. These legumes are also examples of early successional vegetation that provide food and cover for bobwhite quail.

Figure 25. An annual cool-season or warm-season cover crop can be established as a field border or as a refugium for insects while also achieving benefits for pollinators and wildlife.

bumble bees in late spring. They are also a source of other beneficial insects and arthropods that prey on harmful insects (Figure 24).

What are refugia?

Refugia are areas along fields that are established as permanent habitats to attract and be a home for beneficial insects and a diversity of arthropods (Figure 25). A refugium (singular) is made up of early successional vegetation such as a diverse establishment of native plant species that have an extended blooming time. The reason these areas are called refugia is that they are places where beneficial insects and pollinators can reside when other plants and plant communities have either been destroyed by various land management activities or are not present.

Are refugia static?

No, in fact we found that these refugia provided for greater arthropod diversity, or presence of more insect orders, in newly established refugia of only 1 to 2 years old than were found in refugia that had been established longer. One reason for this difference is that the plant diversity is typically at its greatest during the first few years after establishment. Over time, plant succession — the gradual progression of one plant community to another, such as annual plants to an overabundance of perennial plants — occurs and fewer plant species dominate the area.

What can be done to ensure that refugia remain beneficial for pollinators?

Management practices should be conducted to maintain an early successional vegetation stage. For example, prescribed fire should be used three years after establishing the refugia, during the winter or early spring, to open up the existing canopy, reduce competition from aggressive plants, and help improve the germination of native annual forbs and legumes (Figure 26). Light disking can also be used, along with prescribed fire, to achieve these results. Reseeding older stands without fire or light disking did not increase the abundance of annual plants within these native stands.

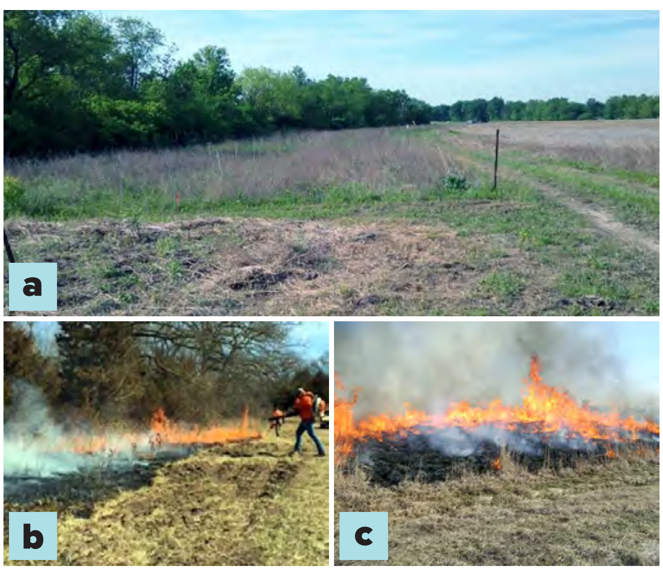

Figure 26. Refugia established along a wooded area and adjacent crop field should be managed to maintain an early successional stage of vegetation promoting annual forbs and legumes (a). Prescribed fire, conducted on a three-year interval, is an excellent tool for maintaining these areas for pollinator and wildlife benefits (b and c).

Is there a benefit to planting native ecotype seed?

Our original hypothesis was that native plants grown from seeds collected within the state (the local ecotype) would provide bloom times that would better coincide with pollinator needs than would plants grown from seeds collected from adjacent states. However, no consistent results were found that would support that hypothesis. Thus, from this preliminary information, it does not appear that seed source matters for pollinator habitat. Bloom time could be extended, however, by using ecotype seeds from more than one state away, such as from Minnesota or Texas.

Since refugia take time to develop, can annual cover crops be used to supplement natives in those areas?

Yes, winter annual cover crops can be a nectar source in the spring, and annual summer cover

Figure 27. A summer cover crop planted adjacent to a wooded area provides excellent habitats for pollinators, beneficial insects and wildlife.

crops can be a source of nectar and habitat later in the year (Figure 27). Often these summer cover crops, such as sunflowers, are blooming during times of the year when a significant percentage of native plants are not blooming. Also, grasses such as millet provide a habitat for arthropods that prey on destructive insects. Winter annual cover crops can be planted in the fall and be followed by summer annual cover crops in the same field.

What is the economic value of a refugia or of a field border?

Field borders and refugia can be planted along wooded edges, fencerows and other areas in which it is not normally economical to produce crops, resulting in greater profit for farmers. These practices are an underused crop management tool (Figures 28 and 29).

For many tree species, the roots of large trees can extend several feet into a field. These roots continually rob nutrients, sunlight and water from the crop, substantially reducing yield. Although it is difficult to estimate exact revenue losses in a specific field given the variability of tree growth, rooting patterns, and a variety of other factors, consider the following example of the economic viability of using field borders:

- A fencerow with dense mulberry, locust, cedar, Osage orange, bush honeysuckle and other species commonly found in unmaintained fences lines two edges of a square 40-acre field planted to row crops.
- Within 30 feet of the tree line, crop yield is reduced 50% in an average year. More than 30 feet from the fence, the reduction in crop yield is minimal.
- Crops rotated are corn, with an average yield 170 bushels per acre, and soybean, with an average yield 55 bushels per acre.

Figure 28. Yields of corn (a) and soybean (b) in rows adjacent to wooded areas are greatly reduced for about 30 or 40 feet from the edge. The economic returns in these areas are negatively affected.

Figure 29. These borders adjacent to a crop field could be established with field borders or refugia, providing greater benefits for wildlife and pollinators, and would likely improve the average crop yield across the field.

Based on these criteria, we calculate that 1.79 acres of the field lie within 30 feet of the overgrown fences. Table 11 shows the impact of the yield lost from the tree line. (Operating costs for corn and soybean production were obtained from the 2025 Missouri Crop Budgets.) Over the course of the two-year rotation, a projected loss of $1,162.89 would be incurred.

Table 11. Reduced crop profitability in proximity to tree line.

	Corn	Soybean
Yield (bushels/acre)	85.0	27.5
Revenue (dollars/acre)	396.65	315.30
Operating costs (dollars/acre)	549.54	375.08
Return over operating costs (dollars/acre)	–152.89	–59.78
Losses due to trees (dollars)	–273.67	–107.00

Conventional field borders or wildlife refugia are not without cost. Establishment costs vary by the type of planting. At a minimum, field borders will likely require some form of mowing annually to prevent the spread of brushy perennials. The Missouri Custom Rates Survey reported rotary mowing costs of roughly $10 per acre. If a nonnative cool-season field border is planted for an estimated $300 per acre, total border establishment and maintenance costs reach $554.90. The cost of investing in a field border would be offset by the crop production losses avoided within three years.

Establishing wildlife refugia may be more costly and comes with different management situations. However, this type of field border may also be eligible for a variety of cost-share programs that provide a cash return for planting wildlife-friendly field borders if management guidelines are followed. In general, losses from trees and other brushy growth on field edges can be detrimental to farm profitability. Although it is true that fewer total bushels are produced from the field in our example, the operating costs generally remain the same for the outside rows of the crop as for the remainder of the field. Eliminating an unprofitable acre from the crop operation increases the enterprise's profitability.

Attracting beneficial insects will result in a reduction in the number of insect pests, which reduces the need for applying insecticides. Refugia also have indirect economic value by acting to prevent water, soil and pesticides from runoff and thus improving water quality. For additional information on the benefits of establishing field borders, refer to MU Extension publication G9421, Field Borders for Agronomic, Economic and Wildlife Benefits.[8]

What are the recommendations for maintaining a sound beneficial arthropod and insect pollinator community?

We recommend implementing the following practices:

- Increase the length of the crop rotations used in row-cropping systems.
- Add cover crops to the existing crop systems.
- Establish refugia and field borders along field edges.
- If there are existing field borders, conduct management practices such as prescribed fire and others that have been described in this report to maintain their ability to provide benefits to pollinators.

These practices will serve to improve the germination of annual seed-producing plants and, thus, add new seed sources into the system. Together, these practices should maintain a well-balanced beneficial insect and pollinator population as well as provide enhanced habitats for wildlife, such as improved nesting, brood-rearing and escape cover required by a diversity of wildlife species.

Cover crops and wildlife habitat

Do cover crops and pollinator plantings provide good habitat for wildlife?

A mixture of legumes and cereal cover crops established in fields provides habitat benefits for wildlife. Mixtures also provide a diverse food source for pollinators as well as food and cover sources for bobwhite quail. Whistle counts for bobwhites — a fall covey call count and a spring male whistle count — were conducted at selected locations, and results indicate a greater number of birds were associated with fields that contained cover crops during the year. With the use of cover crops, the functional use of production agriculture fields by species such as bobwhite quail, various grassland songbirds and other species was extended by about seven months compared to fields that had not been planted with cover crops.

Wildlife habitat evaluation tools, including MU Extension publication MP902, Missouri Bobwhite Quail Habitat Appraisal Guide,[5] were used to rate the habitat attributes provided by crop fields during this case study. The resulting values indicated that cover crops provided improved habitat — including food, nesting and escape cover — during critical winter and spring periods of the year before the cash crop was established. In the spring, arthropod diversity also benefited, which in turn increased the food available for wildlife. Summer cover crops increased these wildlife habitat index values as well, due to the greater abundance of plant diversity that provided foods, in the form of seeds and insects, and sources of cover required for nesting and protection.

In addition, the refugia and field border habitats that were created and managed adjacent to crop fields provided numerous benefits to both pollinators and species of wildlife. Nectar sources were improved and a greater abundance of important food and cover habitats that wildlife require throughout the year were observed as a result of these field border areas.

Are there any concerns related to crop damage caused by wildlife as a result of using cover crops?

Cool-season cover crops maintain a vegetative cover on the field throughout the winter and spring. In some circumstances, vole populations might increase because of the food and cover that is provided. Consider scouting fields to look for signs of vole activity and damage. If large populations are observed, it might be advisable to terminate the cover crop early enough so that the food and cover provided is reduced and there will be little or no damage caused to the planting of corn or soybeans.

Are there any concerns in using fields in agricultural production for wildlife habitat?

As a general rule, all land within a particular agricultural landscape provides some degree of wildlife habitat, as all wildlife species have adapted to a variety of circumstances to survive and reproduce. However, there are potential concerns that need to be considered when using production agriculture fields for seasonal habitats for various wildlife species, such as upland birds, for example. A field's extended exposure to residual and contact pesticides (insecticides and herbicides) can negatively affect upland bird populations by reducing food supplies and available cover. These pesticides can potentially have long-term effects. In addition, various agronomic practices involving the use of farm implements such as mowers, hay balers, combines and others can also negatively impact wildlife, particularly ground-nesting birds, deer fawns and other wildlife that use fields for food and cover.

To determine the potential effects of planting row crops within an established cover crop, we conducted a clay pigeon study at the MU Central Missouri Research, Extension and Education Center. Clay pigeons were used to simulate nest locations within areas of the field in which cover crops were established (Figure 30). Corn and soybeans were then planted using no-till methods with conventional planters to establish the crop during the spring, which coincides with the time when a large percentage of grassland bird nests are initiated.

In simulating clay pigeons as upland bird nests, we found that nest disturbance occurred 70%

Figure 30. A clay pigeon is placed in the cover crop to simulate a bird nest such as northern bobwhite quail. If the clay pigeon breaks during normal crop management activity, then the nest is assumed to be destroyed.

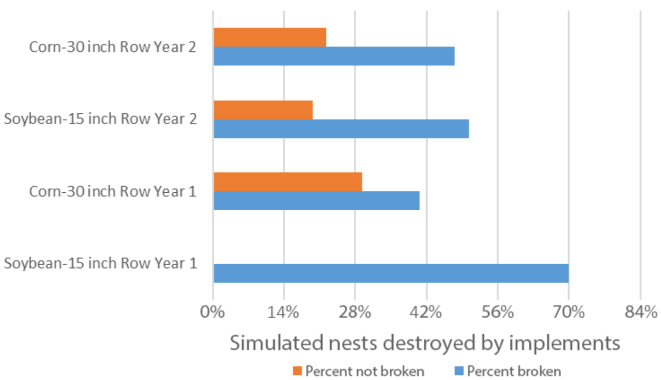

Figure 31. Results from a clay pigeon study conducted at the MU Central Missouri Research, Extension and Education Center during 2014 and 2015 indicating that about 70% of simulated bird nests were destroyed due to implements used during the planting of corn and soybeans in fields with cover crops.

of the time through damage from tires, planters and fertilizer applicators (Figure 31). Although this seems high, these results are similar to the natural nest mortality that results from predators. Nest mortality in crop fields is dependent on numerous factors, from predation to use of farm implements, and this further suggests that nonfarmed, undisturbed areas, located in strategic areas in the landscape, serve as important habitats for ground-nesting birds and other wildlife.

Conclusion

This case study was designed to demonstrate the potential benefits of implementing cover cropping systems for soil health; arthropod diversity, including insects and pollinators; and wildlife habitat benefits within the agricultural landscape of Missouri. This information suggests that the use of cover crops and establishment of adjacent areas around crop fields for insect refugia and wildlife habitat can provide benefits. However, additional research is needed to further quantify the economic benefits and investigate these relationships so that improved management decisions can be made by agricultural producers interested in adopting cover crops and refugia for the purpose of improving soil health, arthropod diversity and wildlife habitat on their property.

Additional resources

- MU Center for Regenerative Agriculture[9] and its Cover Crops[10] page
- USDA Sustainable Agriculture Research and Education, Cover Crops for Sustainable Crop Rotations[11]
- USDA NRCS Missouri's Field Office Technical Guide Website[12] — ecological science tools and community models for evaluating habitat

MU Extension publications

- G9499, Establishing and Managing Cover Crops in Missouri for Wildlife and Pollinator Benefits[7]
- G4161, Cover crops in Missouri: Putting Them to Work on Your Farm[13]
- G9421, Field Borders for Agronomic, Economic and Wildlife Benefits[8]

MU College of Agriculture, Food and Natural Resources videos

- Using Cover Crops[14] — Learn what cover crops to use in Missouri.
- Benefit of Cover Crops[15] — Learn about the benefits cover crops can provide, such as preventing soil erosion, improving soil health, and helping reduce weeds.
- Water Quality and Soil Health[16] — Learn about the affects of cover crops on water quality and soil health.
- Providing Habitat for Pollinators[17] — Learn about establishing and protecting pollinator habitat around crop fields.
- Why Are Pollinators Important?[18] — Learn about the importance of pollinators to Missouri agriculture.
- Establishing Pollinator Habitat: Poor Habitat[19] — Learn how to establish pollinator habitat in poor areas.
- Establishing Pollinator Habitat: Superior Habitat[20] — Learn how to establish pollinator habitat in superior areas.
- Establishing Pollinator Habitat: Marginal Habitat[21] — Learn how to establish pollinator habitat in marginal areas.

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