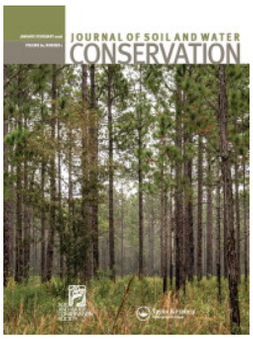

Journal of Soil and Water Conservation

ISSN: 0022-4561 (Print) 1941-3300 (Online) Journal homepage: www.tandfonline.com/journals/uswc20

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To cite this article: David A. Buehler, Brittany Panos, Doug W. Raybuck & Craig A. Harper (24 Apr 2026): Avian use of agricultural cover crop fields during winter, migratory stopover, and the breeding season in Tennessee, Journal of Soil and Water Conservation, DOI: 10.1080/00224561.2026.2629208

To link to this article: https://doi.org/10.1080/00224561.2026.2629208

JOURNAL OF SOIL AND WATER CONSERVATION
https://doi.org/10.1080/00224561.2026.2629208

RESEARCH ARTICLE

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Avian use of agricultural cover crop fields during winter, migratory stopover, and the breeding season in Tennessee

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ABSTRACT

The USDA Natural Resources Conservation Service administers the Cover Crop Initiative through the Environmental Quality Incentives Program to provide technical and financial assistance to agricultural producers establishing herbaceous cover crops to protect fields from soil erosion during the nongrowing season (late fall into spring). Soil retention and water quality benefits of cover crops have been documented, but potential benefits for avian wildlife remain largely unknown. We designed a study in Tennessee to investigate avian use of cover crop fields and selected 86 cover crop and 49 non-cover crop fields as controls for evaluation in 2021 and 2022. We documented the establishment and growth of herbaceous vegetation during winter, spring, and the avian breeding season (May to July), and we compared vegetation within cover crop fields to vegetation in row crop fields without cover crops. We conducted avian surveys on the same dates we measured vegetation, and we compared avian use of cover crop fields to fields without cover crops. We modeled species occupancy for 14 focal species. We calculated species accumulation curves, species richness, and cumulative avian conservation scores to compare avian use of agricultural fields with and without cover crops. We also monitored breeding bird activity on cover crop fields to document potential nesting attempts. Overall, the establishment of cover crops was successful, with more than 80% of the fields having >75% cover in cover crops by spring in 2021 and 2022. Cover crop fields had greater vegetation height and percentage vegetation cover and lower percentage bare ground than row crop fields without cover crops. We detected a slightly greater avian species diversity in cover crop fields (richness = 70) compared to fields without cover crops (richness = 64). Five of 14 focal species occupancy models showed greater probability of use in fields with cover crops than fields without cover crops, whereas only two species showed greater use in fields without cover crops. Species richness per transect and cumulative conservation score per transect were ~10% greater in cover crop fields than in fields without cover crops. We documented limited breeding activity in cover crop fields in early April prior to cover crop termination and subsequent planting. However, given the timing, it is unlikely that cover crop fields supported successful avian nesting, and they may serve as ecological traps. Landowner/producer incentives that promote cover crop termination in early April prior to the beginning of grassland bird breeding season may mitigate potential impacts on avian productivity.

ARTICLE HISTORY
Received April 17, 2025
Revised September 30, 2025
Accepted October 2, 2025

KEYWORDS
avifauna; conservation practice; cover crop; row crops; Tennessee

INTRODUCTION

Agricultural cover crops provide benefits for soil and water conservation, and they may benefit avian wildlife conservation. Cover crops planted during fall in harvested row crop fields improve water quality and reduce soil erosion (Dabney, Delgado, and Reeves 2001), as well as aid in weed, insect, and disease control (Bottenberg et al. 1997; Creamer et al. 1995). Because of these agricultural and environmental benefits, agricultural producers in Tennessee are provided technical assistance and financial incentives administered by the USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) to plant cover crops as part of their row crop management system. In 2016 and 2017, more than 38,000 ha of cover crops were planted on 4,200 fields as a result of NRCS incentive programs in Tennessee. This practice has continued to grow and now is

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/00224561.2026.2629208.

the largest conservation practice administered by NRCS in Tennessee with 67,000 ha y^{-1}, on average, planted in fall cover crops (2019 to 2023, NRCS, unpublished data).

Cover crops have the potential to address some of the concerns relative to the loss of native grasslands as wildlife habitat. Native grasslands are one of the most threatened ecosystems in North America, with an estimated 99% of native grasslands converted to agriculture and other human land uses (Noss and Scott 1995; Samson and Knopf 1994). Because of conversion and fragmentation of native grasslands, grassland birds have declined over the past 50 years and are the most threatened avian taxonomic group in North America (Rosenberg et al. 2019). Prevention of soil erosion and improvement of water quality are the driving forces behind promoting cover crops (Dabney, Delgado, and Reeves 2001; Finney, Buyer, and Kaye 2017; Qi and Helmers 2010; Sainju and Singh 1997). Cover crops in agricultural ecosystems also may benefit grassland birds by providing cover for use during the winter and migration periods and by providing a suitable structure for nesting. Given the increasing adoption of cover crops in Tennessee and elsewhere in row crop agricultural production systems, understanding the dynamics of cover crop establishment, growth, and termination related to avian use, survival, and reproduction has important conservation implications.

Understanding the potential response of birds to a given land management practice is complicated by avian life-history strategies that use different geographic regions via migration or different vegetation types for breeding, brood-rearing, and nonbreeding (i.e., overwinter) and migration life stages. Understanding of avian responses is further complicated by the need to go beyond documentation of cover crop use to understand effects on vital rates related to reproduction and survival (Johnson 2007; Van Horne 1983). Given the scope of the problem, avian studies on cover crops in North America are limited but growing as the practice becomes more widespread. Several studies have documented increased avian use of cover crop fields compared to row crop fields without cover crops during migration and during the breeding season (Figura 2022; Wilcoxen, Walk, and Ward 2018). Few studies have evaluated effects on productivity and/or survival. In Iowa, ring-necked pheasants (*Phasianus colchicus*) seldom used cover crops for nesting (Shirley and Janke 2023). In Kansas, hen pheasants preferred cover crops for brood-rearing but experienced poor brood survival (Godar et al. 2023). Use of cover crops by waterfowl for nesting in South Dakota led to poor nest success (Gallman et al. 2023).

Cover crop fields differ from native or nonnative grass/forb fields as nesting cover because cover crops typically are comprised of annual plants and are terminated in April to May in Tennessee in preparation for planting row crops, such as corn (*Zea mays* L.) or soybeans (*Glycine max* [L.] Merr.) (Best et al. 1995; Dabney, Delgado, and Reeves 2001). Cover crops are terminated by a variety of methods (Alonso-Ayuso et al. 2020), but in Tennessee, cover crops typically are terminated by herbicide application, which kills existing vegetation prior to planting the row crop. We speculated that dead residual vegetation present while the new row crop germinates and grows may attract nesting grassland birds. We also speculated that the timing of cover crop termination also may be critical in terms of whether a given nesting pair can fledge a nest prior to termination and planting the new crop. After cover crops are terminated, row crops are planted, typically with a no-till seed drill, and the new crop germinates and begins growing within one to two weeks. Corn and soybean row crops receive limited use by grassland birds for nesting after the crop germinates and begins growing (Best et al. 1997; Best, Bergin, and Freemark 2001).

Additional information is needed on avian use for passerines and other avian taxa in North America during critical life stages, including the nonbreeding (overwintering) season, migratory stopover, and breeding season. We documented avian species accumulation, occupancy, richness, and similarity during the nonbreeding season, migratory stopover, and nesting season using cover crop fields in Middle and West Tennessee. Our objectives were to (1) document establishment, growth, and termination of the cover crop practice across a broad range of fields in Middle and West

Tennessee; (2) document avian use of cover crop fields during the winter, migratory stopover, and nesting periods; and (3) document the extent to which avian species use cover crop fields to nest. Based on the existing literature, we predicted that vegetative cover and height in cover crop fields would be greater than in non-cover crop fields, and as a result, we expected that there would be greater grassland bird use in cover crop fields than in non-cover crop fields. The study was designed to quantify these expected differences.

MATERIALS AND METHODS

Study site selection

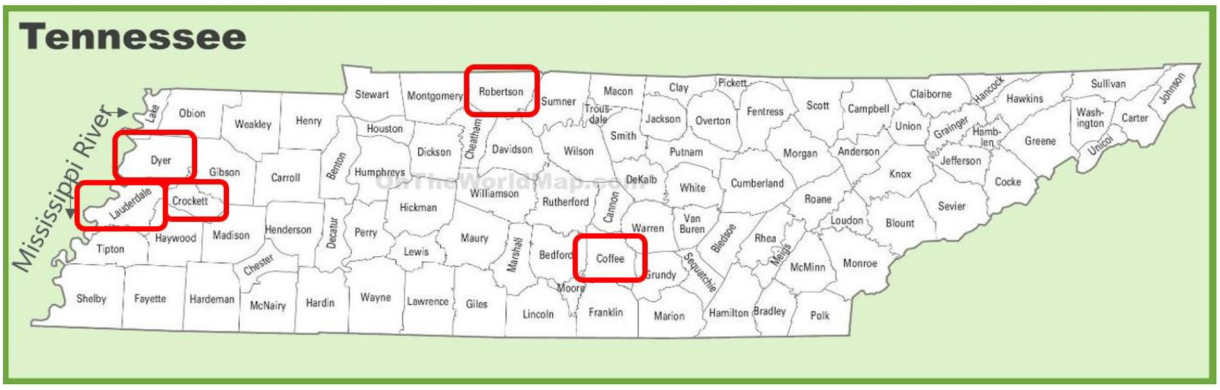
In consultation with NRCS regional biologists, we selected five focal counties for cover crop field evaluation based on the general availability of the practice and on the desire to sample across a broad range of geographic settings in Tennessee. Two counties were in Middle Tennessee (Coffee and Robertson), and three counties were in West Tennessee (Lauderdale, Crockett, and Dyer; Figure 1). The fields selected contained a mixture of cover crop species planted on a rotational basis with either corn, soybean, or cotton (*Gossypium hirsutum* L.) row crops. We also selected minimum tillage row crop fields with no cover crops for comparison. We selected approximately twice as many cover crop fields as non-cover crop fields because we expected greater variability in vegetation on cover crop fields. We obtained a geographic information system (GIS) layer from NRCS and randomly selected fields ≥12 ha and shaped such that we could locate two 100 m avian survey transects that were separated >250 m in each field and were >100 m from the field border. We surveyed a total of 134 fields over the two-year (2021–2022) study period, including 45 cover crop and 24 non-cover crop fields in Middle Tennessee and 41 cover crop and 24 non-cover crop fields in West Tennessee. We surveyed most of the selected fields in 2021 and 2022, though we surveyed some fields in only one year because of changes in enrollment status. Landowners provided us access to their properties and gave us information on establishment dates and cover crop seed mixtures. The vast majority of landowners used a seed mixture specified by NRCS that included crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth), Austrian winter pea (*Pisum sativum* L.), daikon radish (*Raphanus sativus* L.), and triticale (*Triticum aestivum* L.; see online Supplemental Materials Table S1).

Vegetation and avian surveys

We conducted fieldwork from January to July in 2021 and 2022, with the intent of surveying vegetation and birds in each field twice during three consecutive periods: winter (January 15–March 15), migratory stopover (March 16–May 1), and breeding (April 15–July 10). In 2021, we conducted 375 cover crop and 141 non-cover crop field surveys, and in 2022, we conducted 366 cover crop and 226 non-cover crop field surveys.

We documented the establishment and termination dates of cover crops each year of the study. We defined establishment as the date the producer reported they sowed the cover crop. We recorded

Figure 1. Tennessee counties selected for evaluation of avian use of cover crops, 2021 to 2022.



approximate termination dates based on direct observation of field conditions in the spring while conducting vegetation and avian surveys as fields were terminated by either mechanical tillage or herbicide application. We averaged establishment and termination dates by county each year.

Vegetation surveys coincided with bird surveys in January through July, commencing approximately three to four months after cover crops were established in the fall. We used the point-intercept method (Floyd and Anderson 1987) to document vegetation cover at 5 m intervals along the 100 m transect (21 points), and we noted presence of live vegetation, bare ground, and litter. We noted the three most prominent plant species present at each point to document establishment of cover crops, and we measured the average height (centimeters) of live vegetation. Vegetative cover, bare ground, and litter were calculated as the proportion (percentage) of points with live vegetation, bare ground, or litter present out of the 21 points evaluated along each transect.

We conducted avian surveys along the 100 m line transects for 10 minutes per transect to ensure consistent coverage along each transect. We recorded visual and aural detections. We recorded individuals flying over fields as "flyovers" and we excluded them from the analysis because it was unclear how field type influenced flyovers. We conducted surveys between 6:00 a.m. and 12:00 p.m. (Robbins 1981a) when it was not raining or snowing and when wind speeds were <4 on the Beaufort scale (Robbins 1981b).

We conducted breeding bird activity surveys from April 15 to July 10 as part of regular line-transect surveys. We noted breeding behaviors during these surveys (males singing on territory, males defending territory, food carries to the nest, fecal sac removal from the nest, chasing behaviors, and nest building/attendance). We did not systematically nest search on selected fields because of time constraints, but we did search for potential nest sites when bird behavior suggested the bird was actively nesting.

Vegetation and avian statistical analyses

We characterized the landscape composition within a 1 km buffer surrounding surveyed fields because landscape composition is an important determinant of field use by grassland birds (Best, Bergin, and Freemark 2001; Lituma and Buehler 2020). We used the 2020 North American Land Cover layer (30 m pixel resolution) provided by the North American Land Change Monitoring System (NALCMS, http://www.cec.org/north-american-land-change-monitoring-system/) to determine the landcover types present within a 1 km buffer around each field. The percentage of each landcover type within the buffer was calculated in ArcGIS (Esri, Redlands, California) as the number of pixels within one landcover type divided by the total number of pixels within the buffer.

We assigned each plant species documented on our transects to cover crop species (crimson clover, hairy vetch, Austrian winter pea, daikon radish, and triticale), other forb species, or other grass species categories. We calculated the percentage cover of forbs, grasses, and cover crop species for each field surveyed across all survey periods. We arbitrarily defined establishment success based on a standard of ≥75% cover of the field in cover crop plant species during winter and migration periods, prior to termination of the cover crop in the spring.

We conducted generalized linear models (GLM) in R (R Core Team 2020) to evaluate average vegetation height (centimeters), percentage vegetation cover, percentage bare ground, and percentage litter response variables and assess potential differences among cover crop versus non-cover crop field vegetation by season (winter and migration only) and year. Q-Q plots were used to assess normality of residuals and to assess model fits. The vegetation height model was constructed with a gamma distribution that resulted in the best model fit, and the percentage cover models used a binomial distribution. We deemed β coefficients with 95% confidence intervals that did not include 0 statistically significant.

We used species accumulation curves generated by the SpecAccum function in the package "Vegan" in R to estimate the number of species detected within both cover crop fields and non-cover crop fields each year (Oksanen et al. 2007). Species accumulation curves are a good method to describe diversity within study sites when sampling effort differs (Deng, Daley, and Smith 2015; Willott 2001).

We used an occupancy modeling approach for analysis of species presence based on our bird survey data. Occupancy modeling has been used extensively within the field of avian ecology, as it allows for single-species modeling and multi-species modeling (Guillera-Arroita, Kéry, and Lahoz-Monfort 2019). The benefit to using occupancy modeling is that it accounts for imperfect detection, or detection in which individual birds are missed during the survey period for a variety of reasons. We used binomial generalized linear mixed models using the packages "GLMMAdaptive" and "LME4" in program R (Bates et al. 2015; Rizopoulos 2023) for analysis of bird occupancy data. Binomial generalized linear mixed models are ideal when dealing with binary data, which ties well with presence-absence occupancy modeling (Bolker 2015). Using this approach, we determined to what extent field type (cover crop or non-cover crop) was related to avian occupancy for each target species. Besides field type (i.e., enrollment status), we included year as a fixed effect to control for annual variation and transect ID as a random effect to account for nonindependence of repeated surveys. We evaluated zero-inflated negative binomial, Poisson, zero-inflated Poisson, and binomial models for goodness of fit. Based on evaluation of ΔAIC scores, the binomial model was the best fit for the data for the single-species models. For the single-species models, 14 species had sufficient detections (i.e., >20) to permit modeling: American pipit (*Anthus rubescens*), American robin (*Turdus migratorius*), barn swallow (*Hirundo rustica*), dickcissel (*Spiza americana*), eastern meadowlark (*Sturnella magna*), field sparrow (*Spizella pusilla*), indigo bunting (*Passerina cyanea*), killdeer (*Charadrius vocifera*), northern bobwhite (*Colinus virginianus*), red-winged blackbird (*Agelaius phoeniceus*), savannah sparrow (*Passerculus sandwichensis*), vesper sparrow (*Pooecetes gramineus*), Wilson's snipe (*Gallinaga delicata*), and wild turkey (*Meleagris gallopavo*). Each species was assigned to groups based on its status: year-round species were resident species present during all monitoring periods, wintering species occurred only in the wintering period, migratory stopover species were migrants present only during the migration period, and breeding species included year-round residents and other species detected during the breeding season. For species that were not detected throughout the January–July period (i.e., not year-round residents), we only included surveys for occupancy analysis, which were conducted during the period in which a given species was present. For example, indigo buntings are a breeding-only species and were first detected on April 27; thus, the occupancy model for indigo buntings included survey data from the April 27–July 1 period. Based on these breeding season dates, we assumed all individuals detected in a given field were potentially breeding. Individual data subsets were created for indigo bunting, barn swallow, dickcissel, vesper sparrow, Wilson's snipe, American pipit, and savannah sparrow. The other seven species in the occupancy analysis were year-round residents, and their occupancy models were based on all the survey data (i.e., January to July).

To further assess avian use, we developed species richness models (number of species present on each transect per survey visit), analyzed with a Poisson mixed model. To assess the conservation value of the species detected, we incorporated Partners in Flight (PIF) conservation concern global scores (Bird Conservancy of the Rockies 2025) in the analysis with a negative binomial mixed model. PIF is an avian conservation network that assigns landbird species scores based on conservation vulnerability and management need. We used the Continental Combined Score (CCS-max) as an index of species threat level and summed the CCS-max PIF score across species encountered during the study for each individual survey on a given transect to create a response variable (see complete species list with CCS-max scores in Table S2). This response variable was used to evaluate whether the composite bird community present on cover crop fields differed in terms of conservation concern value from the composite bird community using non-cover crop fields. We also calculated a similarity index (percentage of species in common) summarized for all cover crop fields versus non-cover crop fields within each species group (year-round residents, winter residents, migratory species, and breeding species) by year.

RESULTS AND DISCUSSION

Vegetation analyses

Cover crop establishment across all counties ranged from October 10 to November 10, 2021 and 2022, with average establishment dates between October 10 and 20. Termination across all counties ranged from April 10 to May 15, 2021 and 2022, with average termination dates from April 20 to 30. Cover crop establishment success was high in both years. In 2021, >61% of enrolled fields had >75% of the field vegetated with cover crop plants during winter (January through March 15), and >84% of enrolled fields had >75% of the field vegetated with cover crop plants when last sampled in April prior to termination. In 2022, >79% of enrolled fields had >75% of the field vegetated with cover crop plants during winter (January through March 15), and >80% of enrolled fields had ≥75% of fields vegetated with cover crop plants when last sampled in April prior to termination.

Vegetation height (centimeters) differed by field type ($P < 0.001$) and season ($P < 0.001$) but not by year ($P = 0.15$; Table 1). Average height was greater on cover crop fields in winter ($\bar{x}$ = 5.7 cm, SE = 0.4) than on non-cover crop fields ($\bar{x}$ = 4.4 cm, SE = 0.4), and vegetation height was greater on cover crop fields during migration ($\bar{x}$ = 22.1 cm, SE = 1.5) than vegetation height on non-cover crop fields ($\bar{x}$ = 12.9 cm, SE = 1.8). The percentage of live vegetation cover differed by field type ($P < 0.001$) but did not differ by season or by year ($P > 0.05$; Table 1). The percentage of vegetation cover averaged 92.5% (SE = 1.5) on cover crop fields across both seasons and years, compared to 83.0% (SE = 3.3) on non-cover crop fields. Bare ground did not differ by field type, season, or year ($P > 0.05$), but the percentage of litter cover was greater on non-cover crop fields than on cover crop fields ($P < 0.001$). Litter cover averaged 5.9% (SE = 1.3) on cover crop fields compared to 14.0% (SE = 2.8) on non-cover crop fields. Plant species present on cover crop fields were very similar to non-cover crop fields, but cover crop fields were predominantly covered by cover crop–planted species, whereas non-cover crop fields were covered by a diversity of native and nonnative grasses and forbs (Table S1).

Table 1. General linear model results of average height, vegetation cover, bare ground, and litter by season, year, and enrollment type (cover crop versus non-cover crop) for five counties in Middle and West Tennessee, 2021 to 2022.

Vegetation parameter	Beta estimate	SE	*t*/*Z*	*P*
Average height (cm)				
Field type (cover crop)	−0.03	0.01	−5.68	<0.001
Season (winter)	0.13	0.01	12.35	<0.001
Year (2022)	−0.01	<0.01	−1.44	0.15
Vegetative cover (%)				
Field type (cover crop)	0.85	0.21	4.02	<0.001
Season (winter)	0.04	0.22	0.17	0.87
Year (2022)	−0.31	0.21	−1.43	0.15
Bare ground (%)				
Field type (cover crop)	−0.68	0.46	−1.49	0.14
Season (winter)	−0.26	0.49	−0.52	0.60
Year (2022)	−0.90	0.50	−1.81	0.07
Litter (%)				
Field type (cover crop)	−0.86	0.23	−3.68	<0.001
Season (winter)	0.02	0.24	0.84	0.93
Year (2022)	0.61	0.24	2.52	0.01

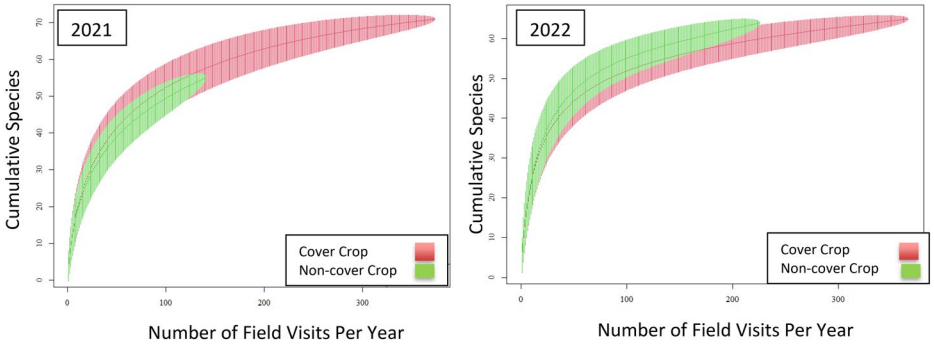
Note: The average height model used a gamma distribution with an inverse link, while the percentage cover models used a binomial distribution with a logit link.

The percentage of cropland within 1 km buffers did not differ between cover crop and non-cover fields ($F = 0.714$, 1 df, $P = 0.46$). Of the eight landcover types within the 1 km buffer (cropland, forest, shrubland, grassland, wetland, urban, water, and barren), cropland was the most prevalent type surrounding both cover crop and non-cover crop fields, averaging 63.6% to 85.3% landcover. Because landscape composition did not differ between cover crop and non-cover crop fields, we did not include landcover type in our occupancy modeling.

Avian analyses

We detected 70 species in cover crop fields in 2021 and 66 species in 2022 (Figure 2; see complete species list with scientific names in Table S2). We detected 54 species in non-cover crop fields in 2021 and 64 species in 2022. In both 2021 and 2022, the 95% confidence bands for the species accumulation curves for cover crop fields overlapped with the 95% confidence bands for the non-cover crop fields when based on a similar number of visits (Figure 2). Based on visual

Figure 2. Avian species accumulation curves based on species detected on transect surveys of cover crop versus non-cover crop fields for 2021 and 2022 in Middle and West Tennessee.



inspection of the confidence intervals, the total species detected would not have differed by field type in either year if sampling rates were equal.

We detected a total of 42 year-round resident species across cover crop and non-cover crop fields in both years. Year-round residents represented 79.1% and 84.5% of all individuals detected in cover crop fields during 2021 and 2022, respectively ($n = 6{,}298$ and $n = 9{,}671$ detections, respectively). Year-round residents represented 74.1% and 83.1% of all individuals detected in 2021 and 2022, respectively, in non-cover crop fields ($n = 2{,}649$ and $n = 5{,}377$ detections, respectively). The similarity index (percentage of species in common) by year for year-round resident species was very high (>85%) in both years (Table 2; see Table S2 for common and scientific names).

We detected only nine winter-only species across cover crop and non-cover crop fields during both years combined. Winter-only species in 2021 consisted of 12.5% of total detections ($n = 998$) in cover crop fields and 20.7% of total detections in non-cover crop fields ($n = 741$). Wintering-only species in 2022 consisted of 2.5% of total detections ($n = 290$) in cover crop fields and 2.37% of total detections ($n = 153$; Table S4) in non-cover crop fields. The most common wintering-only species in cover and non-cover crop fields were the same (American pipit, savannah sparrow, and Wilson's snipe), though relative abundances differed (Table S4). Similarity indices for winter-only species were lower than similarity indices for year-round residents, ranging from 50.0% in 2022 to 60.0% in 2023 (Table 2).

We detected 18 migratory-only species across cover crop and non-cover crop fields in both years combined, only detected during the March 16–May 1 migratory period. Migratory-only species accounted for just 1.5% and 0.8% of total detections in cover crop fields in 2021 ($n = 119$) and 2022 ($n = 92$), and only 0.3% and 0.6% of total detections in non-cover crop fields in 2021 ($n = 12$) and 2022 ($n = 39$), respectively (Table S5). The top three migratory-only species detected in cover crop fields in both years were bobolinks (*Dolichonyx oryzivorus*), blue-winged teal (*Spatula discors*), and greater yellowlegs (*Tringa melanoleuca*). Migratory-only species were seldom detected in non-cover crop fields, with no year-to-year consistency (Table S5). Similarity indices for migratory-only species were very low (<25%; Table 2).

We detected 15 species as breeding-only species across cover crop and non-cover crop fields in both years combined. Breeding-only species consisted of 6.9% and 12.1% of total detections in cover crop fields in 2021 ($n = 546$) and 2022 ($n = 1{,}386$), and 4.8% and 13.9% of total detections in non-cover crop fields in 2021 ($n = 171$) and 2022 ($n = 900$), respectively (Table S6). The most common species in this group were similar in cover crop and non-cover crop fields during the breeding season (barn swallow, dickcissel, and indigo bunting), though relative abundances differed (Table S6). Similarity indices for breeding-only species were very high (>85%; Table 2).

Of the 14 individual species occupancy models, 5 species had greater occurrence in cover crop fields (positive slopes in the models) than in

non-cover crop fields (dickcissel, eastern meadowlark, field sparrow, red-winged blackbird, and savannah sparrow; Table 3). Only 2 species (American robin and killdeer) had greater occurrence in non-cover crop fields than in cover crop fields (negative slope; Table 3). Occupancy for the other species modeled (American pipit, barn swallow, indigo bunting, northern bobwhite, vesper sparrow, Wilson's snipe, and wild turkey) did not show a difference in occupancy rate ($P > 0.5$) by field type (Table 3).

Species richness per transect was ~10% greater in cover crop fields ($\bar{x}$ = 2.05, SE = 0.04) compared with species richness in non-cover crop fields ($\bar{x}$ = 1.85, SE = 0.05, $P < 0.01$; Table 4). The cumulative PIF CCS-max score was also about 10% greater in cover crop fields, on average ($\bar{x}$ = 18.6, SE = 0.04), compared with the cumulative PIF CCS-max score in non-cover crop fields ($\bar{x}$ = 16.6, SE = 0.05, $P < 0.01$; Table 4).

Table 2. Similarity index (percentage of species in common) for cover crop versus non-cover crop fields, summarized by year and season in Middle and West Tennessee, 2021 to 2022.

	2021		2022	
Species group	Total species	Similarity (%)	Total species	Similarity (%)
Year-round residents	38	86.8	40	87.5
Winter-only residents	8	50.0	5	60.0
Migratory only	12	16.7	9	22.2
Breeding only	14	85.7	15	93.3

Table 3. Occupancy estimates (percentage of transects with a given species present ± SE) for most commonly occurring avian species in cover crop versus non-cover crop fields in Middle and West Tennessee, 2021 to 2022.

		Transects with detections	Occupancy estimates (±SE)				
Species	Season[†]		Cover crop	Non-cover crop	Slope	95% CI	*P*
American pipit	W, M	41	0.04 ± 0.01	0.05 ± 0.01	−0.26	−1.00 to 0.47	0.48
American robin	YR	320	0.05 ± 0.01	0.07 ± 0.01	−0.40	−0.80 to −0.01	0.05
Barn swallow	M, B	245	0.15 ± 0.01	0.13 ± 0.01	0.15	−0.19 to 0.50	0.39
Dickcissel	M, B	430	0.19 ± 0.01	0.07 ± 0.01	1.41	0.77 to 2.05	<0.01*
Eastern meadowlark	YR	529	0.18 ± 0.01	0.13 ± 0.01	0.61	0.14 to 1.07	0.01*
Field sparrow	YR	764	0.25 ± 0.01	0.20 ± 0.01	0.46	0.16 to 0.76	<0.01*
Indigo bunting	M, B	990	0.39 ± 0.02	0.42 ± 0.02	0.19	−0.09 to 0.48	0.19
Killdeer	YR	202	0.04 ± 0.01	0.12 ± 0.01	−1.24	−1.76 to −0.73	<0.01
Northern bobwhite	YR	84	0.03 ± 0.01	0.02 ± 0.01	0.27	−0.45 to 0.99	0.47
Red-winged blackbird	YR	564	0.28 ± 0.01	0.22 ± 0.02	0.42	0.09 to 0.75	0.01*
Savannah sparrow	W, M	477	0.20 ± 0.01	0.14 ± 0.02	0.50	0.19 to 0.82	<0.01*
Vesper sparrow	M	12	0.02 ± 0.01	0.03 ± 0.01	−0.53	−1.71 to 0.66	0.38
Wilson's snipe	W, M	63	0.05 ± 0.01	0.04 ± 0.01	0.07	−0.86 to 0.99	0.89
Wild turkey	YR	18	0.01 ± 0.01	0.001 ± 0.01	2.03	−0.24 to 4.30	0.08

Note: Occupancy was calculated using binomial linear mixed models with field type (cover crop versus non-cover crop) and year as explanatory variables. Estimates are pooled across both years.
*Species had greater occupancy in cover crop fields than occupancy in fields without cover crops.
[†]Seasons are defined as W (winter, January 15 to March 15), M (migration, March 16 to May 1), B (breeding, May 1 to July 10), and YR (year-round, January 15 to July 10).

Table 4. Species richness per transect and Partners in Flight (PIF) Continental Combined Score (CCS-max) cumulative values per transect for cover crop and non-cover crop fields in Middle and West Tennessee, 2021 to 2022.

	Means (SE)									
	Cover crop		Non-cover crop		Slope		95% CI		*P*	
Response	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Species richness	1.76 (0.05)	2.36 (0.06)	1.45 (0.07)	2.09 (0.07)	0.19	0.12	0.05 to 0.32	0.04 to 0.20	<0.01	<0.01
PIF CCS-max	15.85 (0.48)	21.52 (0.53)	12.61 (0.63)	19.05 (0.62)	0.23	0.12	0.07 to 0.39	0.02 to 0.23	<0.01	0.02

Note: Slope, confidence intervals, and *P*-values are from negative binomial mixed model analyses comparing response for cover crop versus non-cover crop fields.

Discussion

Use of agricultural cover crops is one of the most extensively implemented conservation practices on private lands in Tennessee, with almost 300,000 ha established from 2019 to 2022 with an annual investment of ~ US$1.5 million. As such, understanding the wildlife conservation value of this practice is important to federal (NRCS), state, and private land managers, biologists, and landowners. We evaluated the implementation of the cover crop practice and documented avian use for two years (2021 to 2022) in five counties in Middle and West Tennessee. Implementation of the cover crop practice was successful across both years. Producers enrolled in the program implemented cover crops on their fields via aerial seeding or drilling. In 61% (2021) to 79% (2022) of enrolled fields, cover crops were established successfully (>75% cover in cover crop plants) by the winter evaluation period (January–February), despite weather events (e.g., snow and ice) that greatly impacted vegetation growth, in some cases for several weeks. By spring, >80% of the cover crop fields were well-vegetated in the planted cover crop species (>75% cover). In a few cases, cover crops never grew on fields for unknown reasons related to a lack of cover crop seed germination. In general, we documented greater vegetation height and ~10% greater vegetation coverage in fields enrolled in the cover crop program compared to non-cover crop fields during both the winter (January–February) and migration (March–April) monitoring periods. The cover crop fields were dominated by cover crop plant species, but also contained additional grass and forb species that were present in non-cover crop fields. Even in non-cover crop fields, however, vegetative coverage was >60% during the winter period and >80% during the migration period, germinated from the seedbank. Greater vegetation coverage on crop fields, regardless of whether it comes from planting cover crops or germination from the seedbank, can yield potential benefits to soil conservation and water quality (Groff 2015).

Both cover crop and non-cover crop fields typically had diverse and extensive forb and grass cover, apparently at sufficient levels to be attractive for avian use. Heterogeneity of plant species can provide benefits in terms of food and cover resources. Most of the fields planted in cover crops were planted with a mixture of species (i.e., legumes, triticale, cereal rye, buckwheat). Although planting cover crops increased vegetation height and cover, the naturally occurring seedbank also created heterogenous species composition on these fields that provided some soil and water protection. GeFellers et al. (2020) also reported similar vegetation composition of fallowed crop fields in Tennessee, revegetated via seedbank response only and revegetated by planting native grasses and forbs.

We documented a diversity of avian species using cover crop fields (70 species), ranging from passerines to upland gamebirds, waterfowl, shorebirds, and raptors, which suggests the practice has potential value for providing avian wintering and migratory stopover habitat. The fields we monitored occurred in landscapes dominated by agriculture, which influences avian use (Lituma and Buehler 2020). However, landscape composition did not differ between cover crop and non-cover crop fields in our study, and therefore did not explain the differences we found. Thus, the differences in avian use we documented in cover crop versus non-cover crop fields reflected differences in avian use in response to the vegetation present on the fields, rather than differences in the landscape composition the fields were located in.

The number of avian species present at the broadest (regional) scale was similar, based on study-wide species accumulation curves. At a finer scale, we documented that cover crop fields also had about 10% greater species richness and cumulative conservation scores (CCS-max) per transect than non-cover crop fields. Occupancy of 5 of 14 focal species modeled (dickcissel, eastern meadowlark, field sparrow, red-winged blackbird, and savannah sparrow) was greater (5% to 12%) in cover crop fields than in non-cover crop fields during winter and migratory periods. These results are consistent with a similar study from Illinois, where cover crop fields had greater avian abundance and species richness than avian abundance and species richness in non-cover crop fields during migration (Wilcoxen, Walk, and Ward 2018). Most of the species with a high conservation score that preferred cover crop fields

(i.e., grasshopper sparrow [*Ammodramus savannarum*], savannah sparrow, field sparrow, dickcissel, and eastern meadowlark) are facultative or obligate grassland species. Grassland species are the most threatened group of birds in North America (Rosenberg et al. 2019); thus, their use of cover crop fields can be seen as a positive benefit of this conservation practice. Further cost-benefit analysis is warranted to determine whether the US$1.5 million annually in landowner incentives in Tennessee is a worthwhile investment given the documented increases in soil and water quality and the ~10% increase in avian use by species of conservation concern.

Avian use during the breeding season of cover crop fields consisted of ~15 different species, very similar to those using non-cover crop fields, but we documented little nesting activity in either field type. Avian use for nesting in Tennessee begins in mid-late April for many species (Giocomo et al. 2008), when vegetation may entice males singing for mate attraction (i.e., songbirds) and females for mate and nest-site selection. Because cover crop termination occurred by mid- to late-April and the new row crop was planted and became established relatively quickly (i.e., ~7 to 10 days), cover crop fields quickly became similar structurally to typical row crop fields. As such, our results were consistent with studies on row crop systems elsewhere in that we documented little nesting activity in cover crop fields (Annis 2019; Best et al. 1995; Shirley and Janke 2023).

Because grassland bird nesting cycles from nest building to fledging are typically ~30 days (Ehrlich, Dobkin, and Wheye 1988), cover crop termination and planting would have to be delayed until late May to allow grassland birds to potentially produce one successful nesting attempt in cover crop fields. Delaying termination and planting until late May is untenable from an agronomic point of view because successful planting and early plant growth are linked to soil temperature and moisture most suitable in late April (Bollero, Bullock, and Hollinger 1996). Alternatively, requiring producers enrolled in the cover crop program to terminate their cover crops by April 15 may discourage most grassland species from attempting to nest in these fields. Encouraging grassland birds to nest elsewhere might be preferable if alternative nesting habitat is available in the landscape.

SUMMARY AND CONCLUSIONS

Cover crops are a conservation practice that is continuing to grow in Tennessee, as well as other regions in the United States and internationally where row crops are produced. Enhancement of soil and water quality (Dabney, Delgado, and Reeves 2001) and the documented modest increases in avian wildlife use for species of conservation concern in our study demonstrate the environmental benefits of this practice. Possible negative effects of this practice involve the encouragement of grassland species to begin nesting in cover crop fields, ensuring failure of their first nesting attempt. Moving the termination dates earlier in April could mitigate this potential negative effect of the practice in grassland-dominated landscapes where grassland bird conservation is a priority.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

FUNDING

The research was funded by the USDA Natural Resources Conservation Service Conservation Effects Assessment Project No. NR193A750023C004. Project sponsors did not contribute to the development of this manuscript.

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