Ring-necked pheasant population and space use response to landscapes including spring cover crops

by

Alixandra Janelle Godar

B.S., University of Wisconsin-Stevens Point, 2011
M.S., Texas Tech University, 2016

AN ABSTRACT OF A DISSERTATION

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DOCTOR OF PHILOSOPHY

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Abstract

Planting spring cover crops as part of a crop rotation is a potential management practice to increase nesting and brood-rearing habitat for grassland birds in agricultural landscapes. Managers consider spring cover crops beneficial for wildlife populations while providing agricultural benefits by converting fallow fields to green fields during the breeding season. Populations of ring-necked pheasants (*Phasianus colchicus*) are declining in Kansas, USA primarily due to intensification of row-crop agriculture reducing availability of quality habitat. Use of spring cover crops may increase recruitment of ring-necked pheasants by providing nesting and brood-rearing habitats when the field would normally be fallow. Plant composition of spring cover crop seed mixes varies based on the relative amount of small grains, grasses, and forbs. To maximize the influence of cover crops on local wildlife, an understanding of how wildlife species use landscapes containing cover crops and the potential role of cover crops on population growth is required. My objectives were to (1) estimate the effect of spring cover crops on ring-necked pheasant population demography, (2) measure brood habitat and resource selection, (3) measure hen habitat and resource selection during the breeding season, and (4) test vegetation and insect composition among cover crop mixes and across other cover types. I compared ring-necked pheasant, plant, and insect response among three cover crop seed mixes and chemical fallow control treatments in 26 study sites on private land in four counties in western Kansas during 2017-2019. The three cover crop mixes were GreenSpring© (73 kg/ha; cool-season peas [*Pisum sativum*] and oats [*Avena sativa*]; 321.4 ha), Chick Magnet© (28 kg/ha; warm-season, broad-leafed forbs; 322.8 ha), and a Custom Wildlife Mix (41 kg/ha; multispecies mix for wildlife; 334.6 ha). In Conservation Reserve Program (CRP) fields within 2 km of treatments fields, I captured pheasants via nightlighting. Captured female pheasants (*n* = 139)

were outfitted with a 15-g necklace-style very-high-frequency transmitter with an 8-hr mortality switch and a unique numbered aluminum leg band. Radio-collared individuals were monitored a minimum of twice a week from capture through September each year to measure movements and habitat use through nesting, brood rearing, and brood break-up periods. When conditions allowed, nesting females were monitored daily to determine nest success and nest hatch day. I conducted weekly vegetation surveys and biweekly insect sweep surveys in cover crop fields and surrounding potential habitat patches (i.e., CRP, native pasture, wheat, and other crop fields). I estimated home ranges for hens with ≥30 locations during the breeding season ($\bar{x}$ = 91.05 ha, SE = 14.43, n = 55). Selection of cover types was based on use versus availability of different cover types within each home range. Every location was assigned a cover type and 2 weekly locations were randomly selected for vegetation and insect surveys with a paired random location. I found that (1) pheasant population growth increased in cover crop fields, (2) broods used cover crop fields, (3) pheasants selected for CRP cover types across all time periods, but resource selection varied based on availability of resources and physiological requirements, and (4) cover crop fields provided more cover and insects than chemical fallow fields. Insect (Wilks $\lambda = 0.07$, $F_{5,376} = 18.66$, $P < 0.0001$, $n = 382$) and vegetation measurements (Wilks $\lambda = 0.15$, $F_{5,3247} = 256.94$, $P < 0.0001$, n = 3,316) varied by cover type. Chick Magnet provided the most forb cover of all cover types and the greatest average count of insects. Pheasant hens showed strong selection for CRP (2^{nd} order: $\lambda = 0.203$, $P = 0.001$; 3^{rd} order: $\lambda = 0.204$, $P = 0.015$). Broods used cover crops, crops fields, CRP, and grass. Cover crops comprised <5% of the landscape though it supported >25% of brood locations. Nest survival and hen survival estimates were lower than recommended for a stable population but pheasant hens with cover crops within their home range showed greater population growth than those without cover crops within their home range. Cover crops placed closely to CRP land may increase local pheasant population growth. Spring cover crops help mitigate the negative effects of intensive agriculture practices on grassland birds by providing additional insect forage and connecting isolated habitat patches during the breeding season.

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David Haukos

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Preface

Chapters are formatted to stand alone for future publication.

Chapter 1 - Ring-necked pheasant hen survival, nest survival and population growth

Introduction

The ring-necked pheasant (*Phasianus colchicus*), hereafter pheasant, is an introduced upland game bird in the United States (Riley and Schulz 2001). The first recorded successful introduction from China into the United States was in the Willamette Valley in Oregon in the 1880s. Now, the pheasant is a naturalized resident of many landscapes, in particular grasslands, and associated croplands of the Midwestern United States (Flake et al. 2012). Pheasants were first established in Kansas, USA in 1906 through a series of releases and captive propagation. Recently, pheasant populations have declined throughout much of Kansas and the Midwest, USA (Flake et al. 2012), leaving hunters and managers concerned about negative population trends (Fig. 1.1; Applegate and Williams 1998, KDWPT 2017). Though the declines are well documented, they have not been linked back to individual population metrics or specific causes. Population declines may be a result of habitat degradation through altered or intensified agricultural practices (Rodgers 1999, Flake et al. 2012), disease, or increased predator density (Frey et al. 2003), all which could lead to reduced survival and reproduction. Understanding causes of fluctuations and long-term trends in local and regional populations are essential to successfully manage pheasant populations.

Pheasant populations fluctuate annually depending on female survival and recruitment rates (Fig. 1.1; Jarvis and Simpson 1978, Flake et al. 2012, KDWPT 2017). Because harvest of female pheasants is not permitted, female survival is primarily related to weather and predation associated with reproductive effort (Snyder 1985, Gabbert et al. 1999, Flake et al. 2012). Recruitment rates need to offset annual adult mortality for stable populations and survival of female pheasants is typically lowest during nesting and brooding (Clark et al. 2008). However, harsh winters can increase mortality and limit the number of females available for breeding in the spring (Flake et al. 2012). Greater winter mortality rates can negatively influence populations such that population recovery may take multiple years (Clark et al. 2008). Chick survival is primarily influenced by weather during the first 10 days post-hatch and greater predation risks until flight capable. Pheasant population abundances can increase during favorable environmental conditions, with populations tripling in one year (KDWPT 2017). For a growing population, nest success rates must be ~42%, overall recruitment rates must be ~0.8 female young per adult female, and chick survival must be >42.5% (Clarke et al. 2008).

Survival rates of female pheasants strongly influence overall population growth (Jarvis and Simpson 1978, Clark et al. 2008). Pheasant survival rates depend on annual environmental conditions, sex and age, time of year (breeding season, fall hunting or winter), and the origin (captive or wild) of the individual (Snyder 1985). Annual survival can be categorized into breeding, fall hunting, and winter seasons. In the northern part of the pheasant range, winter survival rates decrease and predation rates increase relative to increasing winter severity (Gabbert et al. 1999). As weather improves with spring warming, female pheasants face numerous challenges during the breeding season. Mortality rates for female pheasants are greater earlier in the breeding season, with survival approximately 65% and 84% during spring and summer, respectively, combining to 55% across the entire breeding season (Snyder 1985, Leif 1994). Breeding movements, prelaying, and laying during April contribute to lower survival than incubation and brood rearing in May and June (Snyder 1985). Availability of quality habitat during periods with expected low survival may improve female pheasant survival and subsequent breeding success.

Nest-site selection by pheasants varies at both local and landscape scales (Wood and Brotherson 1981). Pheasants nest on the ground in a variety of cover types from fence rows to crop fields (Francis 1968, Dumke and Pils 1979, Wood and Brotherson 1981). Females select vegetation types and nest locations with cooler maximum temperatures and more humid conditions than other sites (Francis 1968). Nest sites also tend to have dense vegetation and more forbs relative to the surrounding area (Matthews et al. 2012*a*,*b*). Female pheasants selected recently disked Conservation Reserve Program (CRP) patches planted with forbs to place nests in Nebraska (Matthews et al. 2012*a*,*b*). Nest success rates increase relative to the amount of grassland in the landscape (Clark et al. 1999). Females will attempt to nest multiple times per season if early attempts fail (Gates 1966, Dumke and Pils 1979). Incubation is approximately 23 days and egg laying takes about 1.3 days per egg (Gates 1966). Initial nest success rates influence pheasant population growth more than renesting success rates (Clark et al. 2008). First attempts tend to have greater success rates than renesting attempts (Clark et al. 1999). In Iowa, success rates of initial nest attempts average 57.3% ± 8.0 and 44.8% ± 6.3 for two sites compared to renesting success rates of 45.6% ± 3.0 and 26.9% ± 11.6, respectively (Clark et al. 1999). This could be a result of the energy already expended by females in their first nesting attempt or changing environmental conditions (e.g., increasing temperature) as the season progresses. Nest success rates were greater for nests initiated before May 16th (35% success rate) than nests initiated after May 16th (24% success rate) in Wisconsin (Dumke and Pils 1979). Nest survival varies by state, which could be due to large-scale land use practices, climate, or other reasons (Flake et al. 2012).

Management efforts generally focus on improving existing habitat patches and adding additional high-quality habitat patches to the landscape. Nesting and brood-rearing habitats are often foci of management efforts to increase annual recruitment. One potential management strategy for increasing brood habitat is through planting of spring cover crops as part of a grain sorghum/corn to winter wheat crop rotation. Spring cover crops can provide additional habitat for females and broods instead of the alternative practice of chemical fallow, potentially increasing chick survival in addition to providing cover and food resources for adults (Clark et al. 2008). Potential cover crop benefits rely heavily on the crop rotation practices and when cover crops can be incorporated. Cover crops are defined by their planting season and offer different benefits (KDWPT 2016*b*). Cover crops fields have greater bird diversity, but mechanistic factors contributing to wildlife diversity or how cover crops actually influence wildlife populations are unclear (Wilcoxen et al. 2018). Currently, cover crops are recommended for landowners with goals to support wildlife but there are minimal data supporting these recommendations. To maximize potential cover crop benefits to pheasant populations, we must identify resources used within cover crop fields to understand how cover crops may influence population trends.

Understanding how spring cover crops affect pheasant population demographics and potential limiting demographic parameters will enhance landscape-scale management efforts. Cover crops may influence both adult breeding season and brood survival rates. My research objectives were to estimate (1) female pheasant breeding survival rates relative to weather and county within the state of Kansas, (2) nest survival rates relative to weather and county within the state of Kansas, (3) nest survival rates relative to cover type, and (4) the effect of spring cover crops on pheasant population growth, including adult and brood survival. I predict lower adult weekly survival rates and lower daily nest survival rates during times with extreme precipitation events because extreme precipitation events can negatively affect adult and nest survival. I expect spring cover crops will increase pheasant population growth by providing additional vegetation and invertebrate resources.

Study Area

My study occurred in two ecoregions of Kansas, USA during the 2017–2019 pheasant breeding seasons: High Plains (Graham and Norton counties) and Smoky Hills (Rooks and Russell counties; Fig. 1.2). Counties were dominated by cropland and interspersed with Conservation Reserve Program (CRP) and native grassland (National Soil Cooperative 1977; 1982*a*,*b*; 1986). Wheat (*Triticum* sp.) was the primary crop in both ecoregions, contributing to >50% of the all cropland. The remaining cropland consisted of corn (*Zea mays*), grain sorghum (*Sorghum bicolor*), soybeans (*Glycine max*), and fallow areas (National Soil Cooperative 1977; 1982*a*,*b*; 1986). A typical crop rotation consisted of corn or grain sorghum and a 12-14-month fallow period followed by winter wheat (Roozeboom et al. 2009, KDWPT 2016*b*).

The High Plains consisted of short-grass prairie with mixed- and western tall-grass prairies (Lauver et al. 1999). The short-grass prairie was dominated by blue grama (*Bouteloua gracilis*) and buffalograss (*Bouteloua dactyloides*) with scattered purple threeawn (*Aristida purpurea*), broom snakeweed (*Gutierrezia sarothrae*), slimflower scurfpea (*Psoralidium tenuiflorum*), and upright prairie coneflower (*Ratibida columnifera*; Lauver et al. 1999). The western tall-grass prairie, in the High Plains, was predominantly comprised of big bluestem (*Andropogon gerardii*) and indian grass (*Sorghastrum nutans*) with intermixed Illinois bundleflower (*Desmanthus illinoensis*), American licorice (*Glycyrrhiza lepidota*), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascophyrum smithii*), common threesquare (*Schoenoplectus pungens*), and sand dropseed (*Sporobolus cryptandrus*; Lauver et al. 1999).

In the Smoky Hills, the Dakota Hills tall-grass prairie is comprised of big bluestem, switchgrass, little bluestem (*Schizachyrium scoparium*), with sideoats grama (*Bouteloua curtipendula*), Fremont's clematis (*Clematis fremontii*), indian grass, prairie spiderwort (*Tradescantia occidentalis*), and Tharp's spiderwort (*Tradescantia tharpii*; Lauver et al. 1999). The mixed-grass prairie in both regions is dominated by little bluestem, sideoats grama, and blue grama (*Bouteloua gracilis*) with ragweed (*Ambrosia psilostachya*), big bluestem, groundplum milkvetch (*Astragalus crassicarpus* var. *crassicarpus*), hairy grama (*Bouteloua hirsuta*), buffalograss, yellow sundrops (*Calylophus serrulatus*), nineanther prairie clover (*Dalea enneandra*), blazing star (*Liatris punctate*), and Indian grass (Lauver et al. 1999).

I defined the study areas within each county as 2 km around fields where I successfully captured pheasants and 2 km around cover crop treatment fields, which comprised a different portion of the study (Figs. 1.2 – 1.9). In 2017, the study area consisted of 9,945 ha in Graham County. In 2018, I expanded into Russell and Norton counties (19,939 ha). The Norton County study areas were located on the Norton State Wildlife Management Area, all other study areas were on private land. In 2019, I added one study area in Rooks County while continuing research in the first three counties (22,958 ha). Annual long-term average precipitation and temperature were similar among counties (Table 1.1). Percent crop coverage was similar among counties. Graham County had 3 percent native grass coverage compared to around 30% in the other counties, but did have the second most amount of CRP coverage (Table 1.2). The number of treatments fields per county varied by year (Table 1.3) with the most treatments occurring in 2019.

Methods

Data Collection

Capture- I used a combination of nightlighting (Gatti et al. 1989, Gabbert et al. 1999, Applegate et al. 2002, Flock and Applegate 2002) and baited air cannon to capture female pheasants from early February to April 15 during 2017–2019. I systematically searched CRP fields with a specially equipped vehicle during the night, with a zig-zag pattern, for pheasants running from the disturbance. Spotlighters shined their lights to confuse birds and keep them on the ground while netters captured birds using salmon nets. Efforts were limited to calm nights (winds <16 km/h) with high relative humidity (>60%) to minimize fire risk. No trapping occurred during rain events.

I fitted captured females with a 15-g necklace-style very-high-frequency (VHF) transmitter with an 8-hr mortality switch (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, MN, USA) and a unique numbered aluminum leg band (Draycott et al. 2006). I measured morphology on captured birds including: sex based on plumage characteristics, mass (g), flattened wing chord length (cm), and tarsus length (mm). Birds were released at the capture site after approximately 10 minutes of handling. Procedures followed the guidelines for handling wild animals required by the Kansas State University (KSU) Institutional Animal Care and Use Committee (IACUC #3831) and State of Kansas Scientific, Education, or Exhibition Wildlife Permits (SC-018-2017, SC-024-2018, and SC-015-2019).

Monitoring- Radio-collared individuals were located a minimum of twice a week (usually >4) from capture through September to monitor through nesting, brood rearing, and brood break-up periods. Locations were determined using a handheld telemetry system, with a three-element yagi and a handheld radio receiver (Communication Specialists, Inc. Orange, CA, USA), to triangulate the location of each individual. All three triangulated bearings were taken within 20 minutes and I kept locations with an error polygon ≤2,000 m^2 in Location of a Signal software (Ecological Software Solutions 2010). Collars in mortality mode were approached to assess mortality causes and retrieve the collar.

When conditions allowed, nesting hens were monitored daily to determine nest success and nest hatch day (Robel et al. 1970). Nest locations, and surrounding cover type, were confirmed with in-person visits when the hen remained stationary for three days. If the hen left the nest, the nest was approached to determine fate. The nest was considered still active if the eggs were whole and warm. The nest was classified as failed if eggs were cold to the touch, eggs were missing, or eggs remains were scattered. Successful nests had at least one egg with a neatly removed egg cap. Brooding pheasants were located daily, and flushed from roosting locations weekly, to count surviving chicks for six weeks after hatch. Flushes were done weekly or when the hen exhibited large-distance movements to confirm the brood was still alive. When the hen was flushed without chicks, she was flushed a second time within a few days to confirm brood absence. Successful broods were hens with chicks at day thirty after hatch.

Weather- Weather varied considerably over the duration of the study (Tables 1.4, 1.5). I used local weather stations from the National Centers for Environmental Information global historical climatology network within each county to determine temperature and precipitation estimates (USW00093990-Graham and Rooks temperature, USC00145852-Norton, US1KSRO0006-Rooks precipitation, USW00093997-Russell). In 2017, there was a late season snowfall event from April 29 – April 30. In 2018, a rainfall event on May 28 with >14 cm of rain in one day led to flooding across the study areas followed by another on June 30 of the same year.

Cover Map- I determined patch types (i.e., cover type) using National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and ground truthing to develop a cover type map of the study area. Patches were classified as cover crop, crop, crop stubble, CRP, grass or other. Grass areas included native grass, rail road tracks, pastures and grass strips. Other included roads, water, trees and manmade structures. Cover type for all marked birds and nest sites was recorded.

Statistical Analysis

I estimated individual survival rates in Program MARK (version 6.1), using known fate models for weekly adult survival (n = 88) and nest survival for daily nest survival estimates (n = 85). I used Program MARK to estimate real and derived survival rates and standard errors. I modeled relationships between survival and weather, year, and county. I used Akaike's information criterion for small sample sizes (AIC_c) to assess individual model performance relative to models in our candidate set (Anderson et al. 2000, Anderson 2008). For adults, I defined the breeding season as April 1 to August 18 (20 weeks). I compared 8 adult survival models including the covariates: constant, time, year, county, average maximum temperature, total precipitation, average maximum temperature + total precipitation, and extreme precipitation events. I considered ≥5 cm of precipitation in a day as an extreme precipitation event.

I compared 9 nest survival models: constant, year, county, time, average maximum daily temperature during incubation, total precipitation during incubation, extreme precipitation events during incubation, early and late season nests (with early nesting occurring before July 1), and early, mid, and late season nests (with early nests before June 11 and late nests after July 18). To estimate survival for the incubation period, I raised daily survival to the 23rd power and used the delta method to calculate the standard error (Powell 2007, Cooch and White 2016).

I also estimated nest survival by cover type. I calculated apparent survival for all cover types by dividing the successful nests by the total nests within each cover type. I estimated daily nest survival in Program MARK (version 6.1) for the three cover types with the most nests (CRP, wheat, and grass) and pooled remaining nests. To estimate survival for incubation, I raised daily survival to the 23rd power and used the delta method to calculate the standard error.

Adult survival and fecundity drive pheasant populations, so to determine the relative effect of cover crops on population growth, I generated age-classified matrix models (Caswell 2001) with subsets of the monitored hens based on the percent of the 95% Kernel Density home range comprised of cover crops. I used the package adehabitatHR in Program R to estimate the 95% kernel density home range for hens with ≥25 locations during the breeding season (Calenge 2006, Aebischer et al. 1993). I created 5 subsets of hens with enough locations to generate home ranges, including hens with no cover crops within their home range (n = 19), hens with >0% cover crops within their home range (n = 36), hens with >10% cover crops within their home range (n = 21), hens with >20% cover crops within their home range (n = 14), and hens with >30% cover crops within their home range (n = 10). I assumed juvenile and adult hens had equal fecundity ($F_J = F_A$) and survival ($S_J = S_A$) for this analysis. I estimated fecundity by multiplying the percent of birds with a successful brood by half the average clutch size (5.15 eggs). I used apparent survival of hens during the cover crop season (May 15 – August 15) for the survival estimates. I derived lambda to estimate population growth during the breeding season using the dominant eigen value of the following matrix:

$$\begin{bmatrix} F_J & F_A \\ S_J & S_A \end{bmatrix}$$

Results

I captured 122 hens over 3 years and monitored 98 nesting attempts and 13 nests found opportunistically. Hen weight averaged 935 g ± 9.9, their flattened wing cord averaged 21.3 cm ± 0.06, and their left tarsus averaged 66.99 mm ± 0.233. Of the hens captured, I generated weekly encounter histories for 88 hens. Other hens were censored because they died or went missing before the time period of interest, died within a week of capture, or dropped their collars. Apparent breeding season survival was 0.398. After flushing, hens did not return to 26 nests within 48 hours of a visit and were excluded from the analysis. Nesting attempts occurred from May 4 to August 31, with only one nest discovered in August. Out of the 22 successful nests (26% apparent survival), 7 resulted in successful broods (31% apparent survival).

Adult survival varied by week but combined to approximately 0.46 (SE = 0.05) across the breeding season (AIC_c = 514.31, $AIC_c\, w_i$ = 0.84; Table 1.6). The lowest week of survival was June 19 – June 25 (0.90 ± 0.03) while the highest survival rate occurred during five weeks, April 1 – April 7, July 8 – July 14, July 29 – August 4, August 5 – August 11, and August 12 – August 18 (1.00 ± 0.00; Fig. 1.11). No other models were competing ($\Delta AIC_c \leq 2$). Year accounted for more variation than the individual weather parameters. The highest weekly survival rate was in 2017 (0.97 ± 0.007) compared to 2018 (0.94 ± 0.010) and 2019 (0.95 ± 0.010). The county model had little support (ΔAIC_c = 8.70, $AIC_c\, w_i$ = 0.01). Rooks County had the greatest weekly survival estimate (0.98 ± 0.02) but a small sample size (*n* = 3) and only one year of sampling. Russell County had the smallest weekly survival estimate (0.91 ± 0.01).

Nest survival estimates were low, with extreme precipitation events explaining the most variation in survival (AIC_c = 360.19, $AIC_c\, w_i$ = 0.33; Table 1.7). Daily survival estimate generated using the extreme precipitation model (β = -0.521 ± 0.341 [SE]) was 0.93 (±0.009), which translates to approximately 17.6% (±0.04) success for a 23-day incubation period. The constant survival estimate was 0.928 (±0.009) and was ranked second (AIC_c = 360.31, $AIC_c\, w_i$ = 0.31; Table 1.7). Survival was not influenced by temperature (β = -0.128 ± 0.296) or total precipitation (β = 0.101 ± 0.272).

Nest success varied by cover type. The greatest percentage of nests were in CRP, but grassy areas had slightly greater nest survival rate (Tables 1.8, 1.9). Wheat fields had the second most nests but did not have very competitive survival rate (Tables 1.8, 1.9).

Hens without cover crops in their home ranges had the lowest relative lambda estimate (λ = 1.36) with the matrix model (Table 1.10). Hen survival estimates ranged from 0.79 – 0.93 and brood survival estimates ranged from 0.11 – 0.20 across the matrices. The lowest hen and brood survival estimates were associated with hen with no cover crops within their home range. Hens with >30% of their home range as cover crop had the largest estimate of lambda (λ = 1.66), closely followed by hens with any cover crop within their home range (λ = 1.61).

Discussion

Ring-necked pheasant populations in Kansas are declining based on lower adult and nest survival rates. My overall hen survival estimate of 46% is slightly lower than 55% in Colorado from April to October (Snyder 1985). Spring hen survival in Iowa (from April 1 – June 3) was 0.79 (± 0.04) and 0.84 (± 0.09; Schmitz and Clark 1999). When my weekly survival estimates from April 1 – June 9 are combined, adult survival is 0.60, lower than the Iowa estimates.

The nest survival estimates were also lower than other studies. The estimated 17.6% nest success rate for my study is lower than the recommended 42% for a growing population (Clarke et al. 2008). Nest success has been as high as 57%, greater than three times my estimate (Clark et al. 1999). Apparent success rates were also greater than my 26% nest success estimate, ranging from 37% in Nebraska (Matthews et al. 2012*a*,*b*) to 68% in South Dakota (Leif 1994). During all three years of the study, extreme weather events negatively affected early nesting attempts. Hens were laying during a late season blizzard in 2017 and flooding in 2018 and 2019. Initial nesting attempts had greater success rates in other studies and these would be the nests negatively affected by the extreme weather events in my study (Clark et al. 1999, Dumke and Pils 1979). Lower hen survival rates during pre-laying, compared to the rest of the breeding season, may have been exasperated by these conditions as well (Snyder 1985, Leif 1994).

The population matrices estimated growing populations, in contradiction with estimated survival rates. These lambda estimates may be artificially inflated by a few factors. First, of the 122 hens captured, I had enough locations to generate home ranges to estimate proportion of cover crops available for only 55 individuals, eliminating half of the mortalities from the matrices, greatly raising the survival rate of females used in this analysis. Second, the time period considered excluded the high mortality rates of the early breeding season because I did not want to include times when the cover crops were not present on the landscape in the analysis. Third, I estimated fecundity assuming the entire clutch hatched and all chicks within a brood suffered the same fate. All matrices should be equally affected by these issues, so though the overall values are not representative of annual population growth, they are representative of growth during the cover crop time period.

Though lambda estimates were inflated, these relative values suggest cover crops positively influencing population growth. Any cover crops within the home ranges increased lambda 18% from 1.36 to 1.61. Although spring cover crop benefits are limited to about a 3-month period of time and may not be enough to counteract the combined negative effects of severe winters, intense hunting disturbance, limited year-round cover, or poor nesting survival, there is an implied benefit from the presence of cover crops on the landscape to population demography of pheasants. Increases in brood and adult survival may increase the number and possibly health of pheasants at the end of the breeding season within a small area.

Management Implications

Region-wide efforts to increase the presence of cover crops across the landscape may positively influence pheasant population growth rates. Producers are often prohibited from adding cover crops to their rotation because of a high initial investment in seed and equipment that takes years to recover through increased harvest profit. Initiating financial programs, as many state and federal agencies and nongovernmental organizations have implemented, to help offset costs during the establishment of cover crops will allow more producers to incorporate cover crops into their rotations. Through financial incentives and continued information campaigns, spring cover crops can replace chemical fallow as the dominant practice across western Kansas. Pairing implementation of cover crops with population monitoring will inform managers when population growth goals are met.

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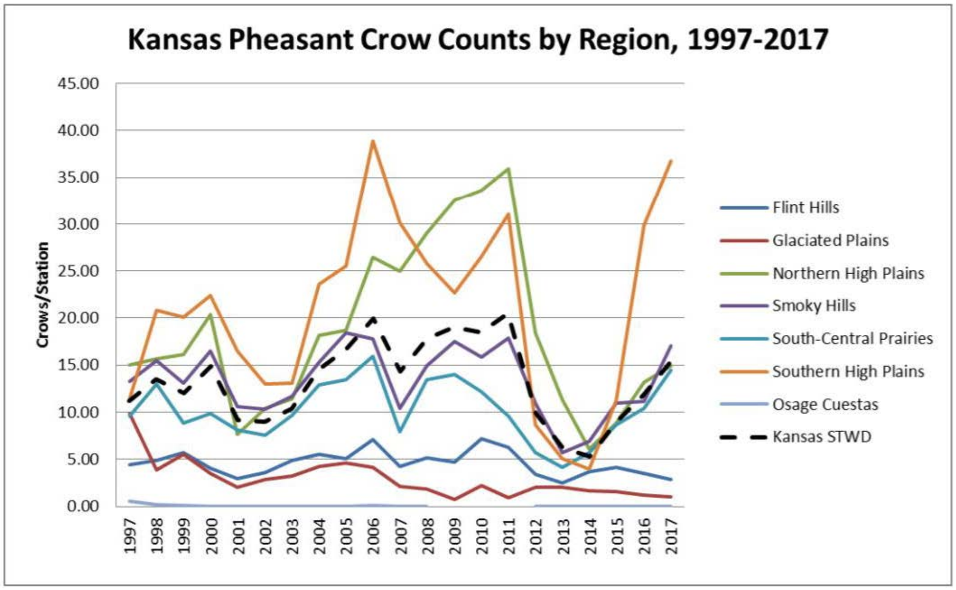

Figure 1.1. Ring-necked pheasant crow counts by region in Kansas from Kansas Department of Wildlife, Parks and Tourism (2017).

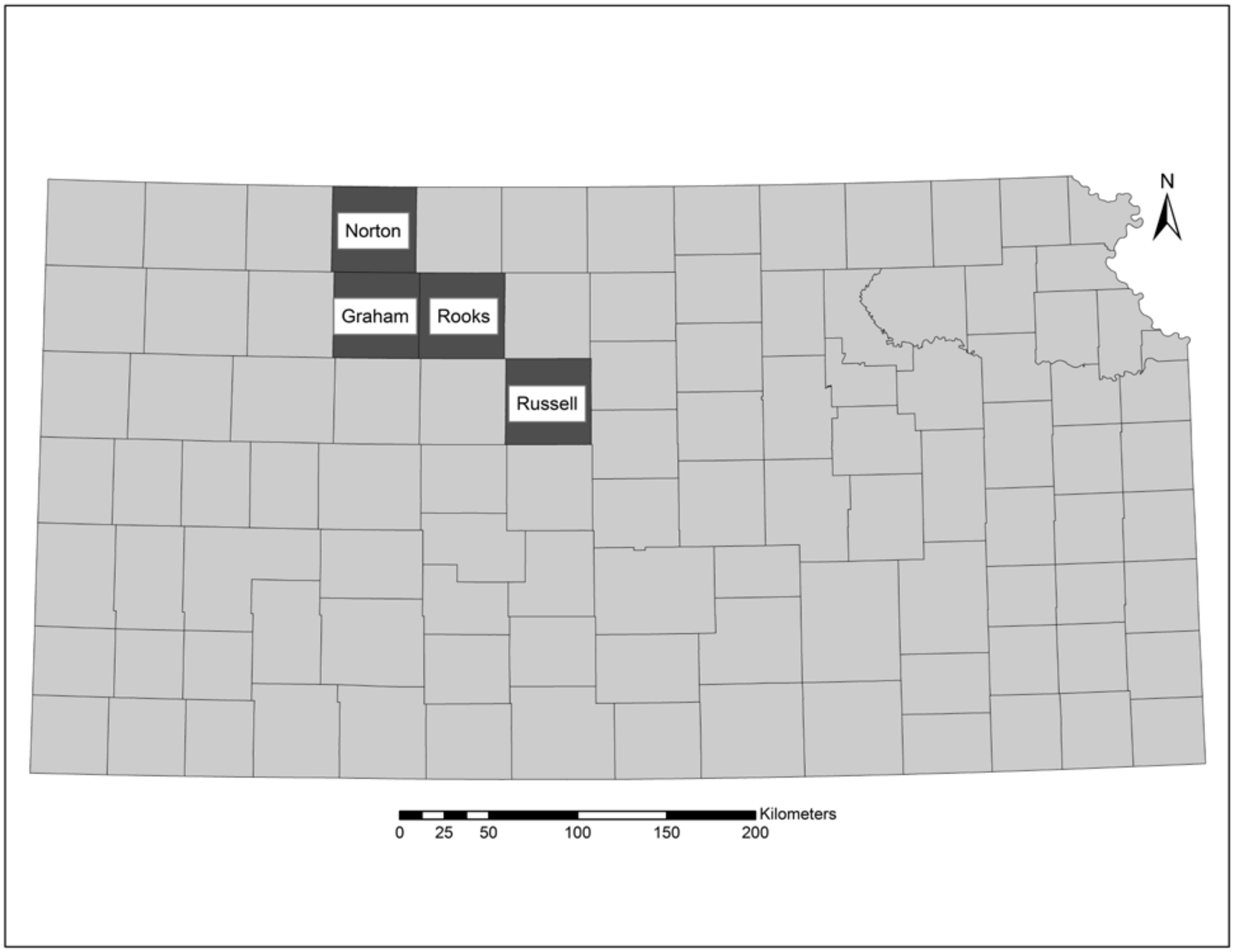

Figure 1.2. Kansas counties with the counties containing the study areas in 2017-2019, Graham, Norton, Rooks, and Russell, in dark grey.

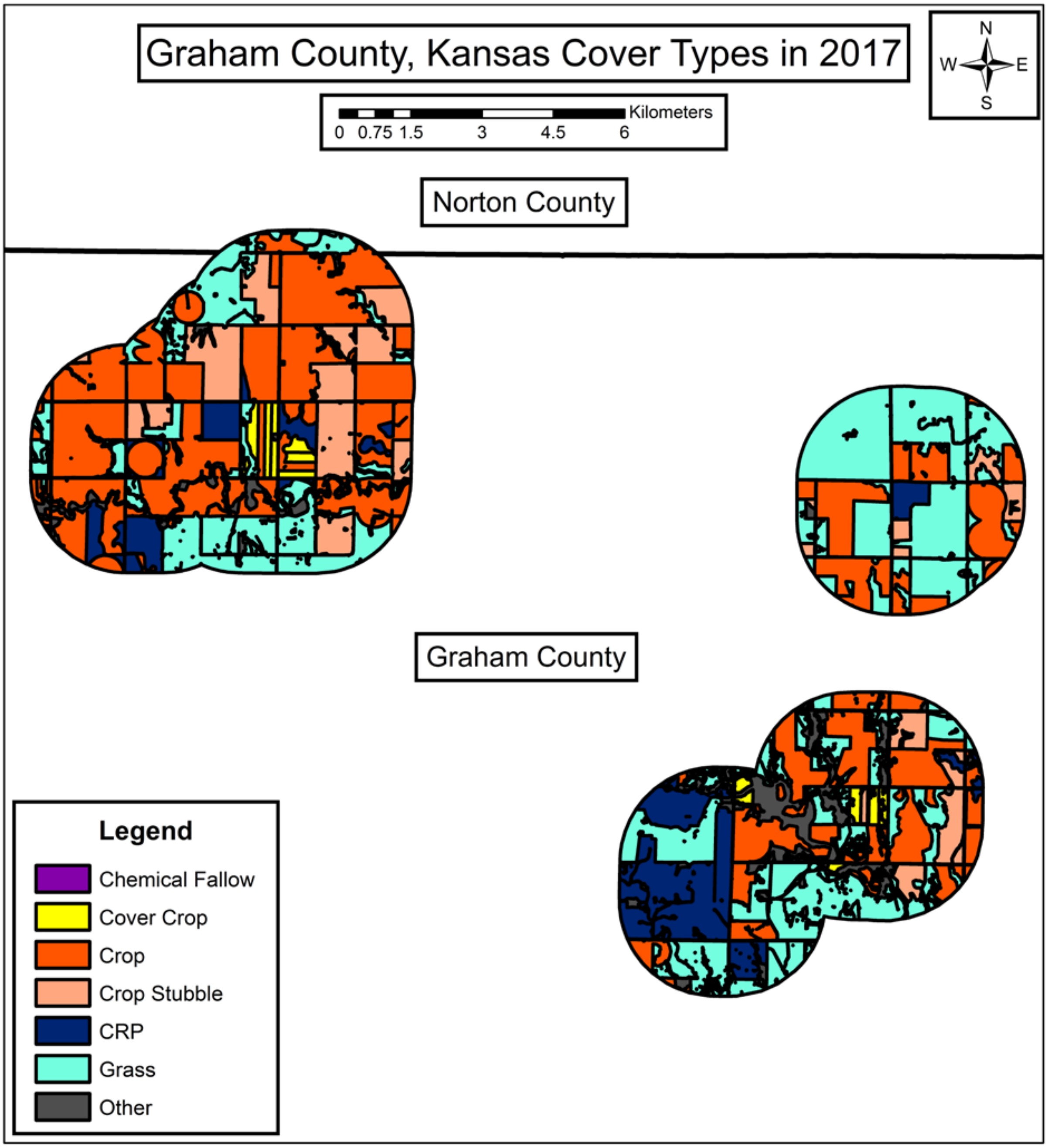

Figure 1.3. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2017 in Graham County, Kansas, USA.

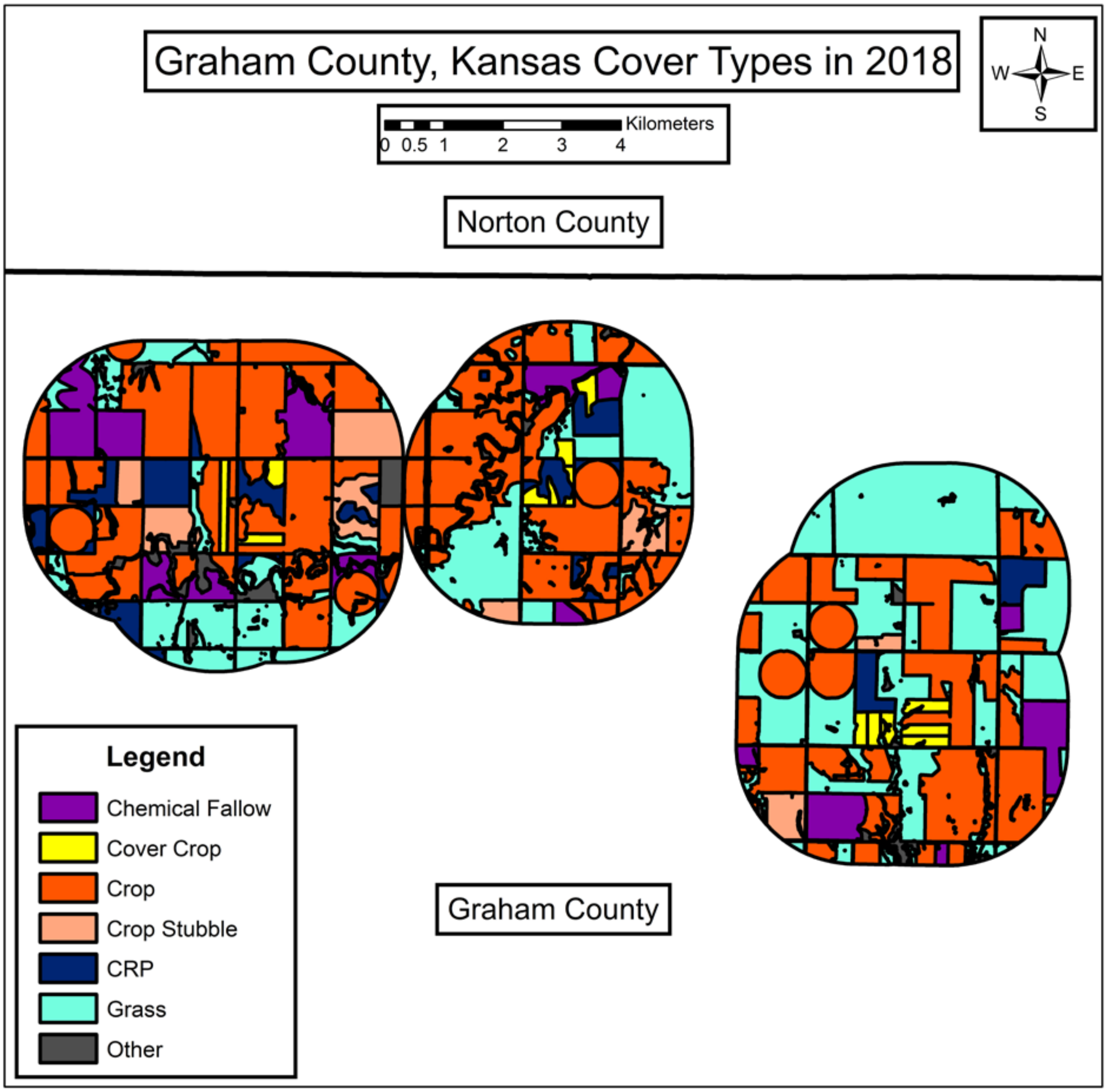

Figure 1.4. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Graham County, Kansas, USA.

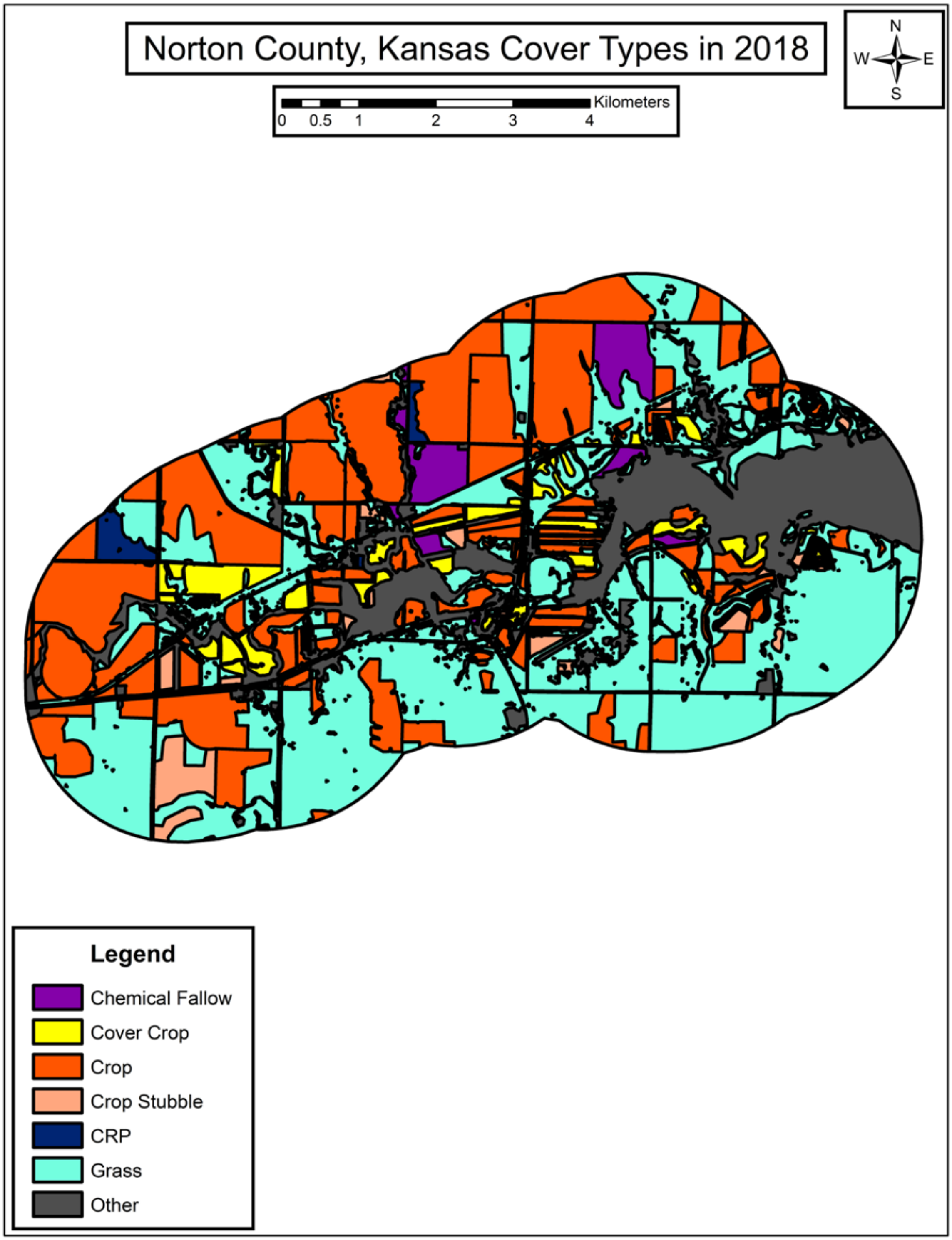

Figure 1.5. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Norton County, Kansas, USA.

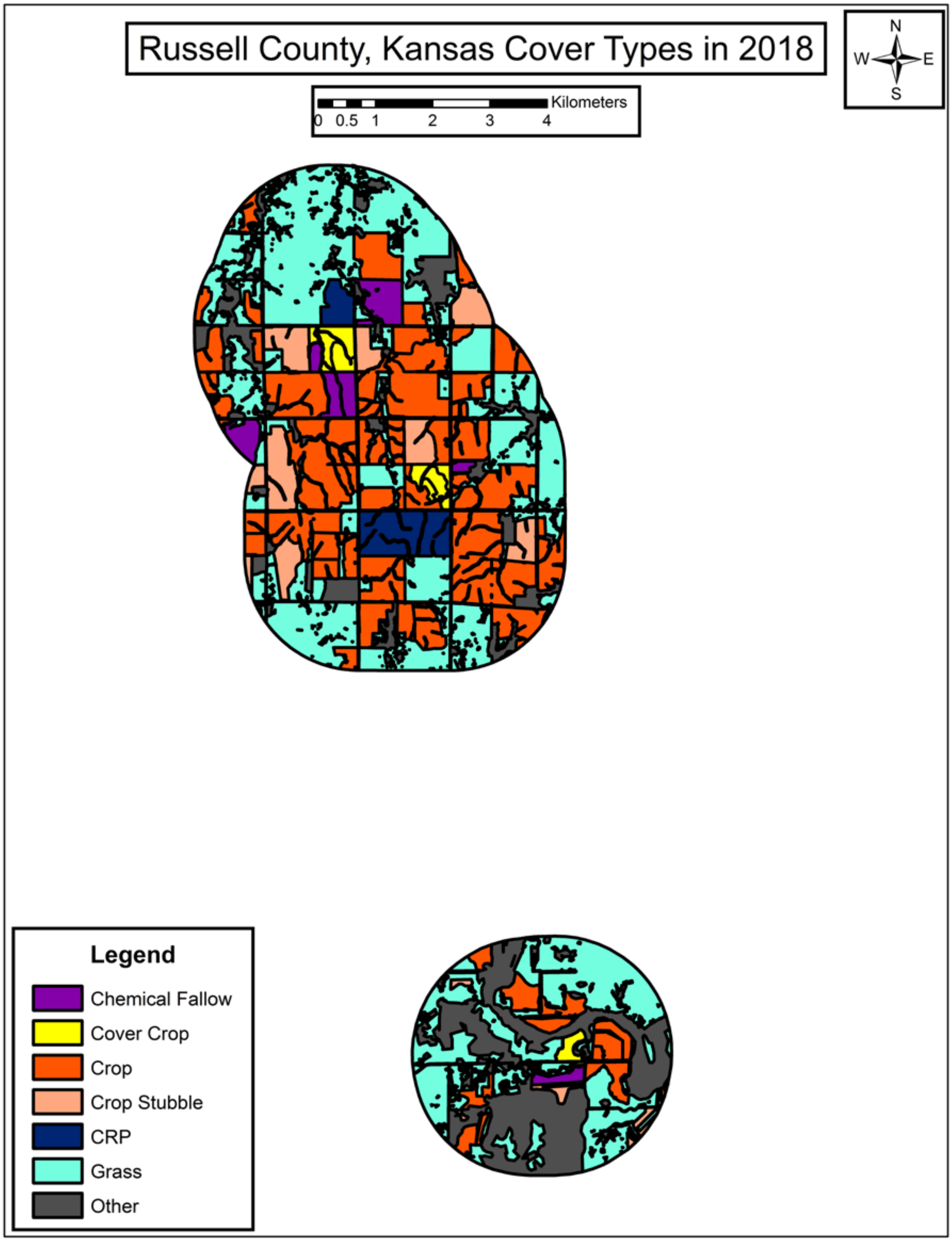

Figure 1.6. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Russell County, Kansas, USA.

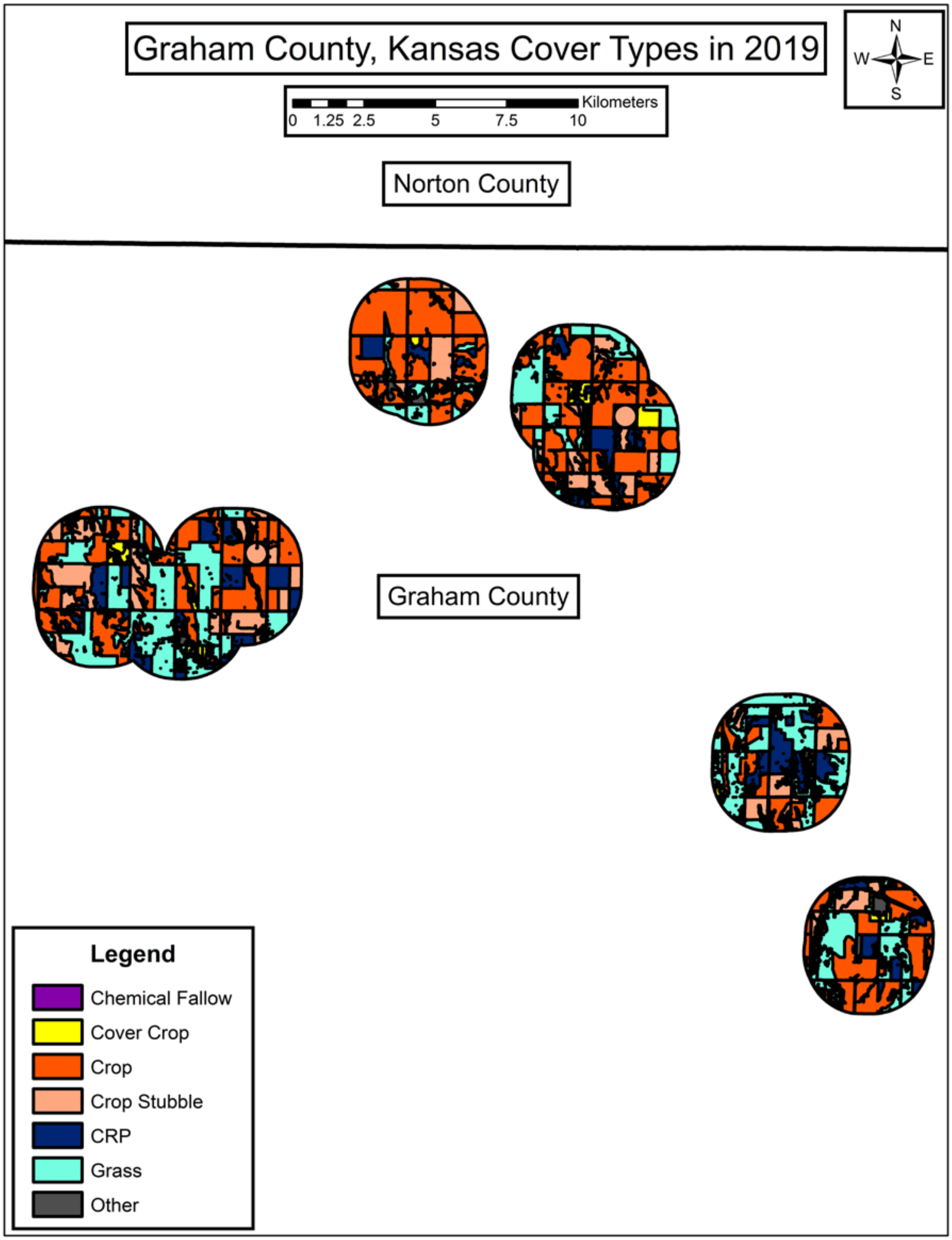

Figure 1.7. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Graham County, Kansas, USA.

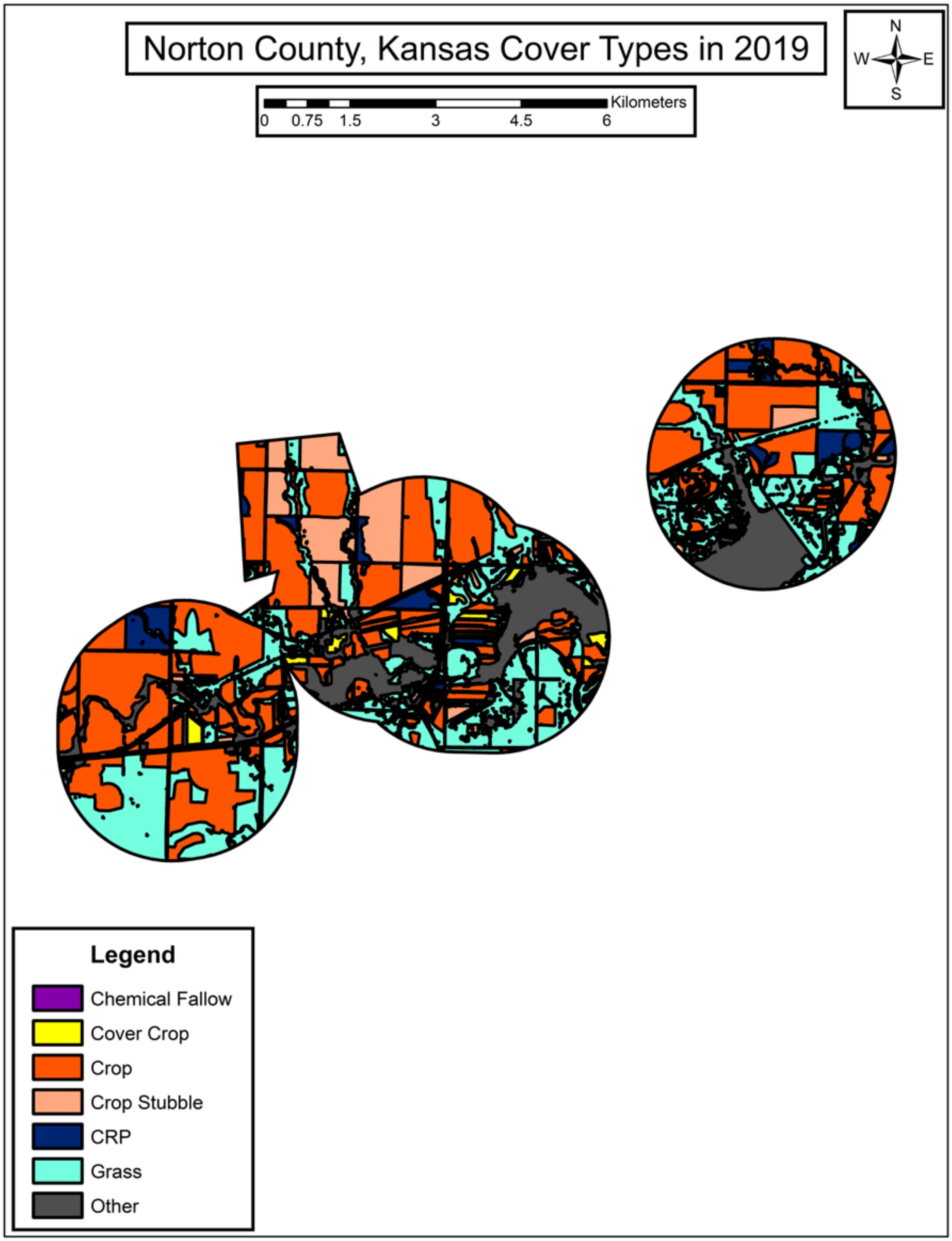

Figure 1.8. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Norton County, Kansas, USA.

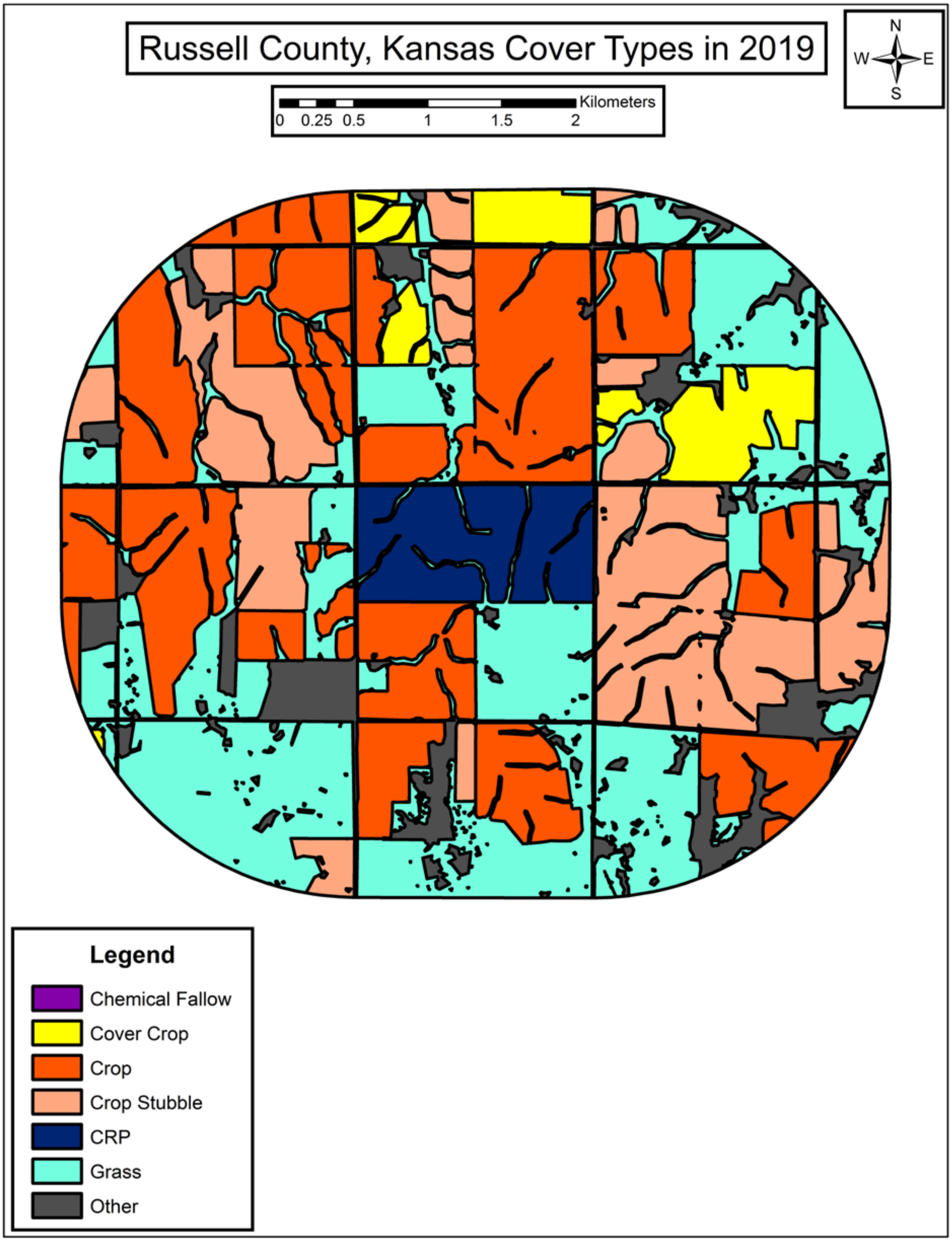

Figure 1.9. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Russell County, Kansas, USA.

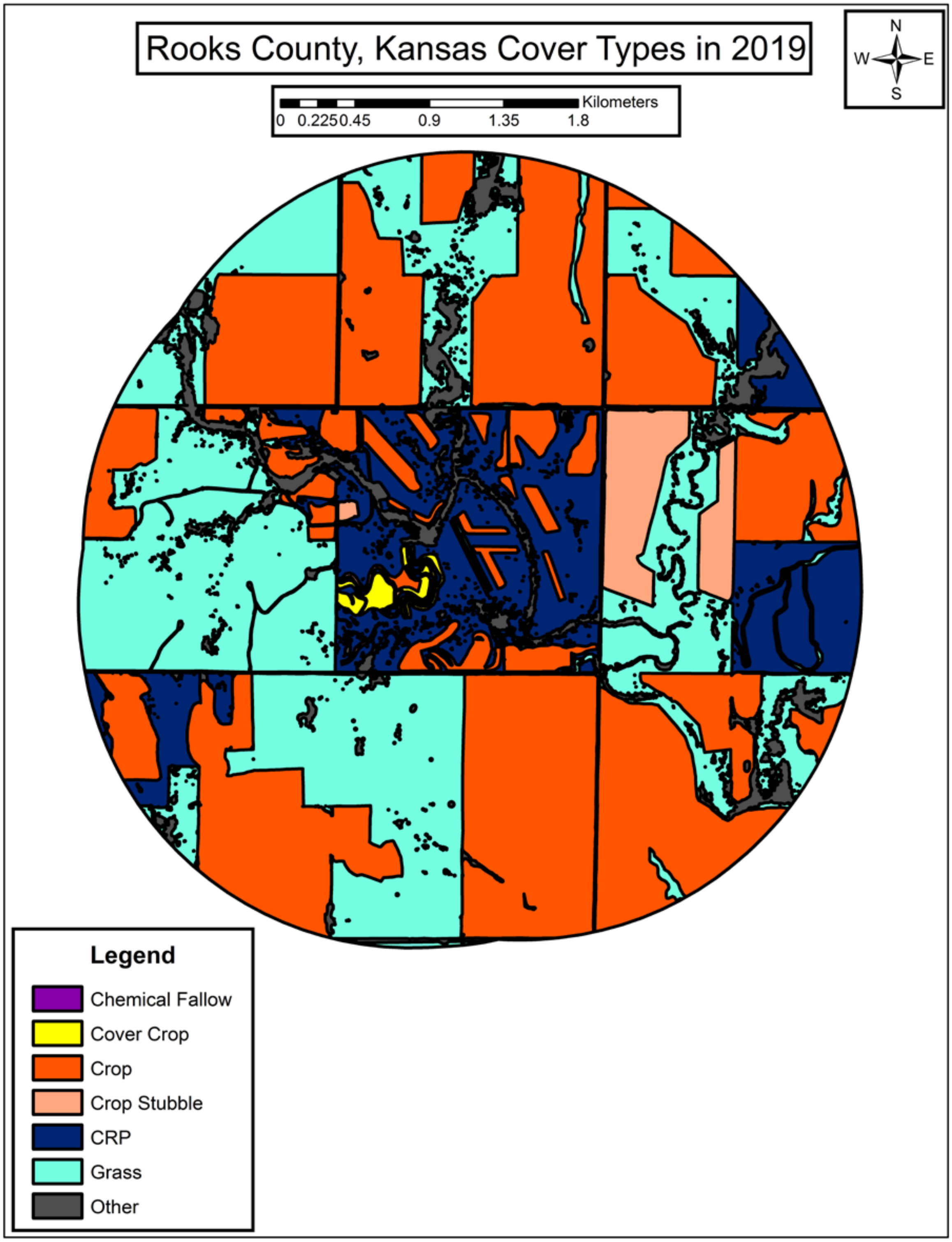

Figure 1.10. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Rooks County, Kansas, USA.

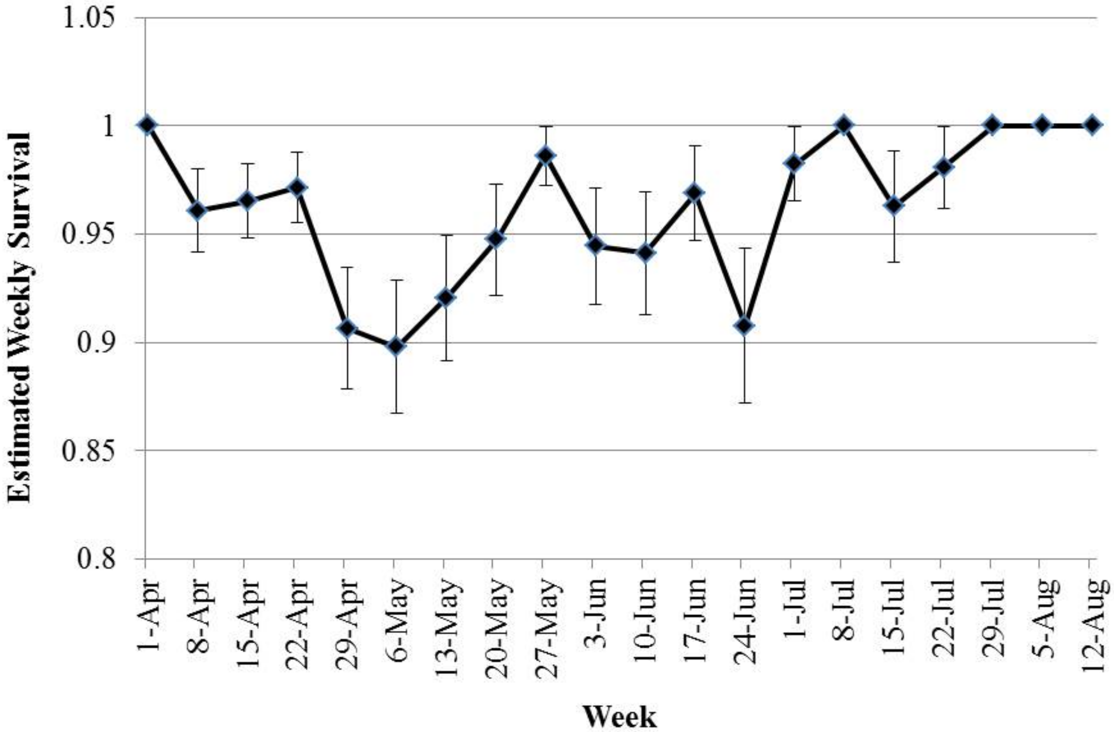

Figure 1.11. Female ring-necked pheasant (*Phasianus colchicus*) weekly survival estimates (*n* = 88) during the breeding season in western Kansas, USA, from 2017 – 2019.

Table 1.1. Summary of climate and weather of study areas in western Kansas, USA, from 2017–2019. Climate data includes long-term averages of annual precipitation totals (mm) and long-term averages of annual average temperature (°C), from 1981 – 2010 annual normal data at three weather stations (USW00093990-Graham and Rooks, USC00145852-Norton, USW00093997-Russell). Weather was collected at the same weather stations. Average temperature was calculated by adding the maximum temperature and minimum temperature and dividing by two. The Norton weather station was inactive for much of 2018.

	County		
	Graham/Rooks	Norton	Russell
Average Annual Temperature (°C)	11.9	11	12.6
Average Annual Total Precipitation (mm)	582.2	656.3	648.5
2017 Average Temperature (° C)	13.2	11.8	13.7
2018 Average Temperature (° C)	12.0	10.3	13.1
2019 Average Temperature (° C)	11.7	10.1	12.1
2017 Total Precipitation (mm)	590.0	325.2	439.6
2018 Total Precipitation (mm)	921.2	256.3	795.5
2019 Total Precipitation (mm)	744.7	322.8	692.8

Table 1.2. Land cover (%) categories in four counties in western Kansas, USA, 2 km around fields where ring-necked pheasants (*Phasianus colchicus*) were captured and around spring cover crop treatment fields, for 2019, delineated from NAIP imagery and confirmed with on the ground visits. Other cover type includes trees, bodies of water, roads, and manmade objects.

	County			
	Graham	Norton	Rooks	Russell
Percent Crop	40	37	42	30
Percent Crop Stubble	13	7	3	18
Percent Cover Crop	2	1	1	5
Percent Grass	3	32	33	32
Percent CRP	12	3	15	5
Percent Other	30	20	6	10

Table 1.3. Summary of average cover crop treatment field sizes (ha) and total coverage (ha) within the study areas, in western Kansas, USA, 2017–2019. Chemical fallow fields were included as a control. Treatments include three spring cover crop mixes and the negative control, chemical fallow. Cover crop mixes include GreenSpring© (73 kg/ha), Chick Magnet© (28 kg/ha) and a Custom Wildlife Mix (41 kg/ha) developed by Star Seed Company (Osbourne, Kansas, USA).

	2017		2018		2019	
Treatment	Average	Total Area	Average	Total Area	Average	Total Area
Graham County						
Chemical Fallow	15.2	45.5	18.2	54.7	N/A	N/A
Chick Magnet	16.8	50.4	13.1	52.4	11.6	93.1
Custom Mix	16.9	50.5	15.3	61.2	10.6	84.5
GreenSpring	16.7	50	13.2	52.8	12.6	100.6
Norton County						
Chemical Fallow	N/A	N/A	9	35.8	7.7	15.4
Chick Magnet	N/A	N/A	4.7	37.5	5	10
Custom Mix	N/A	N/A	8.5	34.1	6.7	20.1
GreenSpring	N/A	N/A	6.8	27.2	4.9	9.8

Table 1.3 continued.

	2017		2018		2019	
Treatment	Average	Total Area	Average	Total Area	Average	Total Area
			Rooks County			
Chemical Fallow	N/A	N/A	N/A	N/A	N/A	N/A
Chick Magnet	N/A	N/A	N/A	N/A	6	18.1
Custom Mix	N/A	N/A	N/A	N/A	6.7	20
GreenSpring	N/A	N/A	N/A	N/A	5.5	16.5
			Russell County			
Chemical Fallow	N/A	N/A	26.9	53.9	8	8
Chick Magnet	N/A	N/A	14.9	29.9	10.5	31.4
Custom Mix	N/A	N/A	13.8	27.7	9.1	36.5
GreenSpring	N/A	N/A	14.8	29.6	8.7	34.9
			All Counties			
Chemical Fallow	15.2	45.5	54.1	144.4	7.85	23.4
Chick Magnet	16.8	50.4	32.7	119.8	33.1	152.6
Custom Mix	16.9	50.5	37.6	123	33.1	161.1
GreenSpring	16.7	50.0	34.8	109.6	31.7	161.8

Table 1.4. Ring-necked pheasant (*Phasianus colchicus*) breeding season (April 1–August 18) weather by county in western Kansas, USA, 2017- 2019, collected at local weather stations (USW00093990-Graham and Rooks temperature, USC00145852-Norton, US1KSRO0006-Rooks precipitation, USW00093997-Russell). Extreme precipitation events were days with ≥5 cm of precipitation in a day. Normal is based on average climate data from the weather station from 1981–2010 (US1KSRO0006 was not available so data are from USW00093990).

	County			
	Graham	Norton	Rooks	Russell
Breeding Season Extreme Precipitation Events				
Normal	0.6	0.7	0.6	0.7
2017	0	0	0	0
2018	2	0	2	2
2019	0	0	2	0
Breeding Season Average Temperature (°C)				
Normal	27.65	26.69	27.65	27.41
2017	28.28	27.44	28.28	27.94
2018	28.01	27.29	28.01	28.77
2019	27.74	26.90	27.74	27.57
Breeding Season Precipitation (cm)				
Normal	31.84	37.82	31.84	39.91
2017	33.56	22.72	31.6	37.62
2018	58.86	16.91	48.44	43.43
2019	44.3	19.79	44.00	46.85

Table 1.5. Ring-necked pheasant (*Phasianus colchicus*) nesting season (May 4–August 31) weather by county in western Kansas, USA, 2017–2019, collected at local weather stations (USW00093990-Graham and Rooks temperature, USC00145852-Norton, US1KSRO0006-Rooks precipitation, USW00093997-Russell). Extreme precipitation events were days with ≥5 cm of precipitation in a day. Normal is based average climate data from the weather station from 1981 – 2010 (US1KSRO0006 was not available so data are from USW00093990).

	Graham	Norton	Rooks	Russell
Nesting Season Average Temperature (°C)				
Normal	30.46	29.61	30.46	30.17
2017	31.17	30.52	31.17	30.75
2018	31.21	30.65	31.21	31.79
2019	29.87	29.23	29.87	29.66
Nesting Season Precipitation (cm)				
Normal	28.40	33.38	28.40	35.52
2017	24.97	21.19	22.37	24.47
2018	59.8	15.04	50.19	41.73
2019	57.33	20.71	49.99	48.62

Table 1.6. Summary of ring-necked pheasant (*Phasianus colchicus*) hens captured and outfitted with radio collars, nesting attempts monitored, nests hatched and broods monitored in western Kansas, USA, 2017–2019.

	2017	2018	2019	Total
Hens Captured	40	47	35	122
Nests Monitored	38	44	16	98
Nests Hatched	6	11	5	22
Broods Monitored	5	7	5	17

Table 1.7. Adult female ring-necked pheasant (*Phasianus colchicus*) breeding season (April 1 – August 18) survival (*n* = 124) model suite results from Program MARK (version 6.1) in western Kansas, USA, 2017 – 2019. I compared 8 adult survival models: constant, time, year, county, average maximum temperature, total precipitation, average maximum temperature + total precipitation, and extreme precipitation events. I considered ≥5 cm of precipitation in a day as an extreme precipitation event.

Model	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	*K*	Model Likelihood	Deviance
Time	514.31	0	0.84	20	1.00	473.73
Year	518.68	4.36	0.09	3	0.11	512.66
Extreme Precipitation Events	521.91	7.59	0.02	2	0.02	517.90
Total Precipitation	522.37	8.06	0.01	2	0.02	518.36
Constant	522.41	8.10	0.01	1	0.02	520.41
County	523.01	8.70	0.01	4	0.01	514.98
Average Maximum Temperature	524.23	9.92	0.01	2	0.01	520.22
Precipitation + Temperature	524.37	10.06	0.01	3	0.01	518.35

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, *K*- number of parameters

Table 1.8. Ring-necked pheasant (*Phasianus colchicus*) nest survival model results for western Kansas, USA, 2017 – 2019. I compared 9 nest survival models: constant, year, county, time, average maximum daily temperature during incubation, total precipitation during incubation, extreme precipitation events during incubation, early and late season nests dividing the nesting season in two, and early, mid and late season nests diving the nesting season into three. Extreme precipitation events were days with ≥5 cm of precipitation in a day.

Model	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	K	Likelihood	Deviance
Extreme Precipitation Events	360.19	0	0.33	2	1.00	356.17
Constant	360.31	0.12	0.31	1	0.94	358.30
Average Maximum Temperature	362.14	1.95	0.12	2	0.38	358.12
Precipitation	362.18	1.99	0.12	2	0.37	358.17
Early and Late Season Nests	364.33	4.14	0.04	3	0.13	358.30
Year	364.34	4.15	0.04	3	0.13	358.31
Early, Mid and Late Season Nests	365.03	4.84	0.03	4	0.09	356.98
County	366.36	6.17	0.01	4	0.05	358.31
Time	543.02	182.83	0	115	0.00	275.39

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, *K*- number of parameters

Table 1.9. Ring-necked pheasant (*Phasianus colchicus*) apparent nest survival by cover type in western Kansas, USA, 2017 – 2019.

Cover Type	Failed Nests	Successful Nests	Total Nests	Apparent Survival
Conservation Reserve Program	34	11	45	0.24
Wheat	12	5	17	0.29
Grass	4	3	7	0.43
Unspecified	3	2	5	0.40
Crop Stubble	3	0	3	0.00
Other	2	1	3	0.33
Chemical Fallow	1	0	1	0.00
Cover Crops (unknown mix)	1	0	1	0.00
GreenSpring	1	0	1	0.00
Hay	1	0	1	0.00
Soybeans	1	0	1	0.00
All	63	22	85	0.26

Table 1.10. Ring-necked pheasant (*Phasianus colchicus*) daily nest survival estimates by cover type category (Program MARK version 6.1) and calculated 23-day incubation survival, from 2017–2019 in western Kansas, USA.

Cover Type	Daily	Standard Error	Incubation	Standard Error
Conservation Reserve Program	0.937	0.011	0.224	0.058
Grass	0.950	0.024	0.307	0.182
Other	0.877	0.032	0.049	0.041
Wheat	0.921	0.022	0.151	0.082

Table 1.11. Ring-necked pheasant (*Phasianus colchicus*) age-stage matrix population model results with subsets of the sample group whose 95% kernel density home range estimate contained a specified percentage of cover crops, in western Kansas, USA, 2017 – 2019.

Percent Cover Crops	Hens	Surviving Hens	Hen Survival	Successful Broods	Brood Survival	λ
0%	19	15	0.79	2	0.11	1.36
>0%	36	32	0.89	5	0.14	1.61
>10%	21	19	0.90	3	0.14	1.52
>20%	14	13	0.93	2	0.14	1.54
>30%	10	9	0.90	2	0.2	1.66

Chapter 2 - Ring-necked pheasant brood resource selection and movements in agricultural landscapes

Introduction

There is limited knowledge on survival and habitat use by ring-necked pheasant (*Phasianus colchicus*; hereafter pheasant) chicks due to the logistics of monitoring chicks. Chick survival directly following hatch (i.e., <10 days old) strongly influences recruitment and subsequent population trends (Hill 1985, Riley et al. 1998, Riley and Schulz 2001, Clark et al. 2008). Availability of quality brood-rearing habitat, allowing for easy movement and providing abundant insects and other invertebrates, may be a limiting factor for pheasant chick survival and recruitment but interactive effects of juxtaposition with nesting and escape cover, landscape-scale resource selection, and movement capacity of chicks remain poorly understood (Warner 1979, Doxon and Carroll 2010). There is little knowledge on brood survival, movement patterns, resource selection, and diet within the Midwest, USA but some studies indicate variability across the occupied range (Hill 1985, Flake et al. 2012). Providing brood-rearing habitat in close proximity to nesting habitat is important for chick survival as chicks in broods with larger home ranges have lower survival rates (Hill 1985). Chick access to quality habitat may be limited by potential travel distance. Common management recommendations place brood-rearing habitat in close proximity to nesting habitat to increase access for chicks.

Recommendations for how to create additional brood cover vary depending on crop type and rotation to maximize benefits for both the producer and local wildlife in row-crop dominated landscapes (KDWPT 2016, Pheasants Forever 2020). A typical crop rotation practice in western Kansas includes herbicides to maintain fallow fields after corn (Zea mays) or grain sorghum (Sorghum bicolor) harvest in the fall until winter wheat (Triticum sp.) is planted the following fall (~12-14 months; Roozeboom et al. 2009). Under this management practice, nesting and brood-rearing efforts for pheasants and other birds fall within the period when the field is fallow and few resources are available. An alternative management practice is to plant spring cover crops which are planted in March or April and terminated in June or July. By planting spring cover crops, producers benefit from increased organic matter, nitrogen fixing, soil nutrient movement, reduced weeds, and reduced soil compaction and erosion (Villami et al. 2006, Wayman et al. 2014, Ladoni et al. 2016). Managers consider spring cover crops a potential practice for increasing local pheasant recruitment rates while also providing agricultural benefits by converting fallow fields to green fields during the breeding season.

Wildlife, including pheasants, may benefit from the additional cover and food resources provided by spring cover crops (Jeliazkov et al. 2016, KDWPT 2016, Wilcoxen et al. 2018). Many spring cover crop seed mixes contain small grains, which pheasants use as nesting and brood-rearing sites (Warner 1979, Flake et al. 2012, Wilcoxen et al. 2018). Other mixes contain a wide variety of forbs, which attract invertebrates, providing additional food resources for broods. Producers can select mixes to potentially provide nesting habitat, brooding habitat, or both (KDWPT 2016, Wilcoxen et al. 2018). Companies have commonly developed commercial seed mixes, but will often create custom mixes of varying complexity by request. Simple mixes can contain two plant species, whereas more complex mixes can contain approximately a dozen species. Although planting cover crops is considered beneficial for most wildlife species by decreasing homogeneity of agricultural landscapes (Jeliazkov et al. 2016), wildlife responses to different seed mixes are relatively undocumented.

To maximize benefits for pheasant broods, managers require information on pheasant brood resource selection and movements within the agricultural landscapes. Planting spring cover crops and management of existing Conservation Reserve Program (CRP) patches are potential strategies for increasing nesting and brood-rearing habitat and enhancing interconnectedness of these habitat patches in agricultural landscapes. The addition of cover crops will alter the landscape by providing an alternative cover type for brood-rearing. My research objectives were to assess (1) movement of pheasant broods among and use of potential habitat patches within a landscape dominated by row-crop agriculture and (2) test resource selection of vegetation structure, vegetation composition and invertebrate community structure by brood-rearing hens. I hypothesized pheasant hens will use spring cover crop fields when raising a brood due to their insect diversity and high percentage of forbs compared to other available cover types (Chapter IV). I predicted pheasant broods would use areas with greater insect diversity and percent composition of forbs.

Study Area

My study area included two ecoregions of Kansas during the 2017–2019 breeding seasons: High Plains (Graham and Norton counties) and Smoky Hills (Rooks and Russell counties; Fig. 2.2). Counties were dominated by cropland and interspersed with Conservation Reserve Program (CRP) land and native grassland (National Soil Cooperative 1977; 1982a,b; 1986). Wheat is the primary crop in both ecoregions, with >50% of the cropland planted to wheat. The remaining cropland consisting of corn, grain sorghum, soybeans (Glycine max), and fallow areas (National Soil Cooperative 1977; 1982a,b; 1986).

The High Plains consists of short-grass prairie with mixed- and western tall-grass prairies (Lauver et al. 1999). The short-grass prairie consists of blue grama (Bouteloua gracilis) and buffalograss (B. dactyloides) with scattered purple threeawn (Aristida purpurea), broom snakeweed (Gutierrezia sarothrae), slimflower scurfpea (Psoralidium tenuiflorum), and upright prairie coneflower (Ratibida columnifera; Lauver et al. 1999). The western tall-grass prairie, in the High Plains, is predominantly comprised of big bluestem (Andropogon gerardii) and indian grass (Sorghastrum nutans) with intermixed Illinois bundleflower (Desmanthus illinoensis), American licorice (Glycyrrhiza lepidota), switchgrass (Panicum virgatum), western wheatgrass (Pascophyrum smithii), common threesquare (Schoenoplectus pungens), and sand dropseed (Sporobolus cryptandrus; Lauver et al. 1999).

In the Smoky Hills, the Dakota Hills tall-grass prairie is comprised mainly of big bluestem, switchgrass, little bluestem (Schizachyrium scoparium), with sideoats grama (Bouteloua curtipendula), Fremont’s clematis (Clematis fremontii), indian grass, prairie spiderwort (Tradescantia occidentalis), and Tharp’s spiderwort (Tradescantia tharpii; Lauver et al. 1999). The mixed-grass prairie in both regions is dominated by little bluestem, sideoats grama, and blue grama (Bouteloua gracilis) with ragweed (Ambrosia psilostachya), big bluestem, groundplum milkvetch (Astragalus crassicarpus var. crassicarpus), hairy grama (Bouteloua hirsuta), buffalograss, yellow sundrops (Calylophus serrulatus), nineanther prairie clover (Dalea enneandra), blazing star (Liatris punctate), and Indian grass (Lauver et al. 1999).

I defined the study areas within each county as 2 km around fields where I successfully captured pheasants and 2 km around cover crop treatment fields, which comprised a different portion of the study (Figs. 2.3–2.10). In 2017, the study area consisted of 9,945 ha in Graham County. In 2018, I expanded into Russell and Norton counties (19,939 ha). The Norton County study areas were located on the Norton State Wildlife Management Area, all other study areas were on private land. In 2019, I added one study area in Rooks County while continuing research in the first three counties (22,958 ha). Annual long-term average precipitation and temperature were similar among counties (Table 2.1). Percent crop coverage was similar among counties. Graham County had 3% native grass coverage compared to around 30% in the other counties, but did have the second most CRP coverage (Table 2.1).

Methods

Data Collection

Capture- I used a combination of nightlighting (Gatti et al. 1989, Gabbert et al. 1999, Applegate et al. 2002, Flock and Applegate 2002) and baited air cannon to capture female pheasants from early February to April 15, 2017 to 2019. Nightlighting required a team of five, including a driver, two netters, and two spot-lighters. I systematically searched CRP fields with a specially equipped rig during the night, with a zig-zag pattern, for pheasants running from the disturbance. Spot lighters shined their lights to confuse the birds and keep them on the ground while the netters used salmon nets to capture birds. Efforts were limited to calm nights (winds <16 kmph) with high relative humidity (>60%) to minimize fire risk. No trapping occurred during rain events for the safety of the birds. I fitted captured females with a 15-g necklace-style very-high-frequency transmitter with an 8-hr mortality switch (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, MN, USA) and a unique numbered aluminum leg band (Draycott et al. 2006). I measured morphology features on captured birds including sex based on plumage characteristics, mass determined by a spring scale (g), flattened wing chord length (cm), and tarsus length (mm). Birds were released at the capture site after approximately 10 minutes of handling. Procedures followed the guidelines for handling wild animals required by the Kansas State University Institutional Animal Care and Use Committee (IACUC #3831) and State of

Kansas Scientific, Education, or Exhibition Wildlife Permits (SC-018-2017, SC-024-2018, and SC-015-2019).

Monitoring- Radio-collared individuals were monitored a minimum of twice a week (usually >4) from capture through September to monitor through nesting, brood rearing, and brood break-up periods. Locations were determined using a handheld telemetry system, with a three-element yagi and a handheld radio receiver (Communication Specialists, Inc. Orange, CA, USA), to triangulate the location of each individual. I used Location of a Signal software (Ecological Software Solutions 2010) to estimate error polygons and continued taking bearings until three bearings were taken within 20 minutes and estimated an error polygon ≤2,000 m2. When conditions allowed, nesting hens were monitored daily to determine nest success and nest hatch day (Matthews et al. 2012). Brooding pheasants were triangulated daily and flushed from roosting locations weekly to count surviving chicks for 6 weeks after hatch. Flushes were done weekly or when the hen exhibited large distance movements to confirm the brood was still alive.

Surveys-I collected vegetation and insect data at triangulated brood locations within 10 days of a location when conditions and access were possible. I recorded patch type at the survey location and also used National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) and ground truthing to develop a cover type map of the study area. Patches were classified as cover crop, crop, crop stubble, CRP, grass, or other. A random paired location within 300 m of the estimated used point and within the same patch was used to assess within patch or point-scale selection (4th order selection; Johnson 1980).

I measured vegetation composition with a Daubenmire frame and visual obstruction with a Robel pole. Composition surveys measured the percent cover of bare ground, litter, forbs, warm-season grasses, cool-season grasses, woody species greater and less than 1.5 m, crop, and standing crop stubble within a 60-cm Daubenmire frame at the estimated and random location points and 4 m to the north, south, east, and west of each point (Daubenmire 1959). Litter (unrooted, dead vegetation) depth was measured in the northeast corner of each frame using a ruler (cm). I gently inserted the ruler into the litter, careful to push the litter aside instead of downwards. Visual obstruction surveys measured the highest dm with 100%, 75%, 50%, 25% and 0% visual obstruction of the Robel pole from the cardinal directions from 4 m away at 1 m above ground (Robel et al. 1970). I estimated an index to overhead cover by subtracting the light intensity (kLux) at ground level from the light intensity at 1 m above ground to determine the light blocked by vegetation (Extech® EasyView Light Meter, Extech Instruments, Nashua, NH, USA).

I conducted invertebrate sweep surveys at used and random locations in 2017 and 2018. Random distances and bearings were generated in Microsoft Excel (Microsoft Corporation, Santa Rosa, CA, USA) using the random number generator. After the used location surveys were completed, the next combination of distance and bearing was paced out. Transects started at the estimated brood location or random location. I took 100 sweeps heading north and depositing collected invertebrates in a gallon-sized plastic bag. I collected three transects per location, taking five paces to the east and turning around between the first two transects and turning west between the second and third transects (Sullins et al. 2018). Insects were classified by order and length before being counted, dried to a constant mass, and weighed (g).

Statistical Analyses

To summarize movement patterns, I measured the distance from the nest to the first triangulated location of the brood, the maximum distance between brood locations, and the maximum distance between the geographic mean center of all of the known brood locations to an individual location. All known brood locations were assigned to a cover type of CRP land, grassy areas, crop fields harvested the year of the location, crop stubble (fallow fields), cover crops, or other.

I compared the proportion of cover types within female home ranges to the proportions of cover types to the brood locations. Brood sample sizes were small (n = 25) so I pooled data across years. The 95% Kernel Density hen home ranges were generated in Program R, version 3.4.1, using the adehabitatHR package. The breeding season home ranges included points from May 15 to August 15 of the year of interest and counted nest locations once. I generated selection rankings and ratios using the adehabitatHS package in Program R (Calenge 2006, Aebischer et al. 1993).

I compared used to random locations using two techniques. First, I used a multivariate analysis of variance (MANOVA) to compare vegetation and invertebrates among used and random locations. I used Resource Selection Functions to determine which vegetation and insect variables influenced use by brooding hens (Manly et al. 2002, Keating and Cherry 2004). Triangulated locations were assigned a "1" for used and random locations were assigned a "0" in a logistic regression framework. I used Akaike's information criterion for small sample sizes (AICc) to assess model performance (Anderson et al. 2000, Anderson 2008). Vegetation and insect variables were analyzed in separate model suites. Visual obstruction readings were assessed in one model suite with other vegetation characteristics analyzed in a separate model suite. Competing vegetation models (<2 ΔAICc) within each model suite were combined and then included in a final model suite (Anderson et al. 2000, Anderson 2008). Insect orders that comprised $<10\%$ of the total biomass or count data were pooled for analyses, including Ephemenopteran, Hymenopteran, Mantodean, Neuropteran, Odonata, Phasmatodean, Psocopteran, Thysanopteran, Aranean, and Ixodidan. I analyzed Coleopteran, Dipteran, Hemipteran, Lepidopteran, and Orthopteran as individual variables. I defined "Richness" as the number of orders present in the sample. Insect models were single variable, linear models (15 models). The VOR model suite contained 10 models: 0% VOR, 25% VOR, 50% VOR, 75% VOR, 100% VOR, quadratic 0% VOR, quadratic 25% VOR, quadratic 50% VOR, quadratic 75% VOR, and quadratic 100% VOR. The vegetation composition model suite contained 14 models: average percent grass, average percent forb, average percent vegetation (grass + forb + crop), average over head cover (light difference), average percent bare ground, average percent ground (bare ground + litter), average percent litter, quadratic average percent grass, quadratic average percent forb, quadratic average percent vegetation (grass + forb + crop), quadratic average over head cover (light difference), quadratic average percent bare ground, quadratic average percent ground (bare ground + litter), and quadratic average percent litter. I limited models to one variable due to inherent correlation between measurements.

Results

I captured 122 hens and monitored 98 nesting attempts. Of the 22 successful nests, there were 7 successful broods that had ≥1 chick with hen at 30 days post-hatch (32%) with 5 monitored in 2018 (Table 2.2). Greater than half of the brood locations were from 2018 (148 out of 244). Five broods were not with the hen the day after hatch for a morning brood flush or any following flushes. During 2018, successful broods were found primarily in grassy areas and cover crop fields even though cover crops were the least common cover type in all study areas (Fig. 2.11). Only 5 out of 17 of the initial locations after hatch were located within CRP even though 53% of nests (n = 83) were found in CRP.

Brood movements were limited to within 500 m of the mean center and initial locations within 200 m of the nest location (n = 18; Table 2.3). The maximum initial movement that I measured was <500 m. Average maximum distance between points was slightly larger at about 700 m. Broods did not tend to make long linear movements, but instead short distance movements that changed direction.

Though movements were small, broods were found in multiple cover types, averaging 2.8 out of 6 cover types for their triangulated locations. Brood locations were almost equally distributed between cover crops, crops, CRP, and grass (Fig. 2.12). Brood use of cover types differed from their availability on the landscape. Of the four used cover types, crop had the largest presence on the landscape, with coverage reaching 42%. Cover crops had the smallest presence on the landscape with ≤5%. Crop stubble and other cover types had very few locations.

Brood patch use was similar to hen home range patch composition. There was not selection for a specific cover type for brood-rearing locations within the hen's home range (λ = 0.36, P = 0.55, n = 16 hens). The rankings, in order of least to most selected, are crop, crop stubble, other, cover crops, CRP, and grass. The grass category included native grass, pasture, train tracks right-of-way, and grass strips. Cover crop (W_i = 1.31, SE = 0.51), CRP (W_i = 1.41, SE = 0.37), and grass (W_i = 1.20, SE = 0.34) had selection ratios of greater than one, indicating they were used more than available. Crops (W_i = 0.71, SE = 0.17), crop stubble (W_i = 0.92, SE = 0.38), and other (W_i = 0.21, SE = 0.14) categories were used less than available. Of the locations in cover crops, 58% were in custom mix fields, which contained grass and forbs. Only 17% were in Chick Magnet, a forb-only blend.

There was no difference between used and random locations for invertebrate metrics (Wilks λ = 0.998, $F_{1,362}$ = 0.23, P = 0.87). I also compared used to random locations for vegetation surveys using two MANOVAs, one for visual obstruction measurements (0%, 25%, 50%, 75%, and 100% VOR) and one for vegetation composition measurements(average percent grass, average percent forb, average percent vegetation, average percent bare ground, average percent ground [bare ground and litter], and average overhead cover). Used and random locations were similar for both visual obstruction (Wilks $\lambda = 0.988$, $F_{1,422} = 1.12$, $P = 0.35$) and vegetation composition (Wilks $\lambda = 0.992$, $F_{1,245} = 0.34$, $P = 0.875$).

Insects found at brood locations did not have a clear distinction compared to random locations ($n = 364$) within patches. The top-ranked models ($\Delta AICc \leq 2$) indicate brood locations were associated with more Hemipteran biomass ($\beta = 0.76 \pm 0.51$ [SE], $P = 0.13$), less Dipteran biomass ($\beta = -5.29 \pm 3.96$ [SE], $P = 0.18$), and less Lepidopteran biomass ($\beta = -0.68 \pm 0.50$ [SE], $P = 0.18$; Table 1; Anderson et al. 2000, Anderson 2008). Though selected as the models with the most support, none of the betas differed from zero ($P \geq 0.05$). Models of total insect count ($\beta = 0.76 \pm 0.51$ [SE], $P = 0.13$) and total insect biomass ($\beta = -0.000059 \pm 0.001077$, $P = 0.96$) indicated nonsignificant negative relationships.

Vegetation models had a clear top model. Brood locations were associated with more vegetation ($\beta = 0.0037 \pm 0.0042$, $P = 0.37$), less litter ($\beta = -0.0051 \pm 0.0064$, $P = 0.43$), less ground ($\beta = -0.0027 \pm 0.0046$, $P = 0.56$), and taller vegetation ($\beta = 0.0017 \pm 0.0238$, $P = 0.94$; Tables 2.5, 2.6). Though selected as the models with the most support, none of the betas differed from zero ($P \geq 0.05$).

Discussion

Pheasant broods in my study moved shorter distances than pheasant broods in other studies. Median initial movements from the nest were <150 m and subsequent individual locations were closely clustered with a farthest distance between two locations within a home range of 692 m ± 73. Brood-rearing hens in South Dakota had a larger average major axis, the farthest distance between two locations within a home range, of 1.14 km (Hanson and Progulske 1973).

In spite of their small movements, broods used a variety of habitat types. The cover types of the brood locations were not different from the hen home ranges and incorporated multiple patches. Cover crops were a small percentage of the landscape but widely used by broods. Broods favored highly diverse mixes containing both grass and forb species. Use of crop fields and CRP remained relatively consistent among the three years possibly due to their prevalence across the landscape. The majority of nests were in CRP but use decreased after hatch. Though active crop fields may provide late season cover, crop stubble fields were rarely used. The year with the greatest brood survival, had increased use of spring cover crop fields and grassy areas compared to other years.

Brood-rearing hens selected for increased percent vegetation and increased Hemipteran biomass, supporting previous studies. Quality brood-rearing habitat allows for easy movement and provides abundant insects (Warner 1979, Doxon and Carroll 2010). Insect remains in fecal samples show chicks forage on Delphacids (Hemipterans), Heteropterans, and Lepidopteran larvae in Illinois (Hill 1985). In western Kansas, hand-raised pheasant chicks selected for Homopterans, Hemipterans, and Coleopterans but the majority of their diet was Hymenopterans and Coleopterans (Doxon and Carroll 2010). In Nebraska, pheasant brood fecal samples frequently contained Coleopterans, Hymenopterans, and Hemipterans (Smith et al. 2015). Hemipterans, though very common in the samples, were a small proportion and selected less than available (Smith et al. 2015). Though I found pheasants in areas with greater amounts of Hemipterans, chicks may be consuming less common orders. Weak patterns in point vegetation and insect communities imply management focusing on landscape composition may provide more benefits to chicks than focusing on improving a singular patch type.

Point vegetation and invertebrate characteristics varied by cover type (Chapter IV). However, pheasant broods did not select locations based on point vegetative and invertebrate characteristics. Broods do not appear to target specific point characteristics when they could by selectively utilizing the different cover types. Their limited mobility may be forcing them to select locations based on proximity and available cover types.

Management Implications

Adding cover crops to the landscape will increase the amount of available brood-rearing habitat while decreasing the presence of a poorly used cover type, chemical fallow. Adding spring cover crops to the list of brood-rearing habitat cover types and incorporating the management practice into financial incentive programs for pheasant habitat will positively affect available brood-rearing habitat. It would be beneficial to incentivize seed mixes that include grass and forb components. Unlike some other brood-rearing habitat methods which require conversion of a section of crop field to an alternative cover type, incorporating cover crops will not disrupt the landowner's crop rotation. Establishment of spring cover crops in fields adjacent to nesting habitat should be prioritized for the incentives. Incentives should focus on landowners who have been using cover crops for less than 5 years since financial benefits of cover cropping take a few years to establish.

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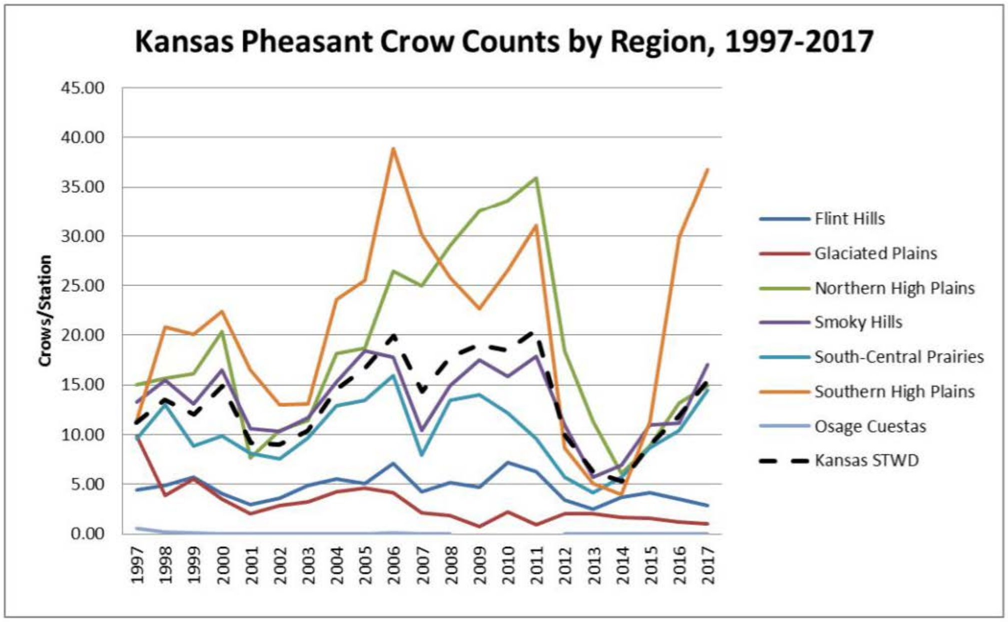

Figure 2.1. Ring-necked pheasant crow counts by region in Kansas, USA, from Kansas Department of Wildlife, Parks and Tourism (2017).

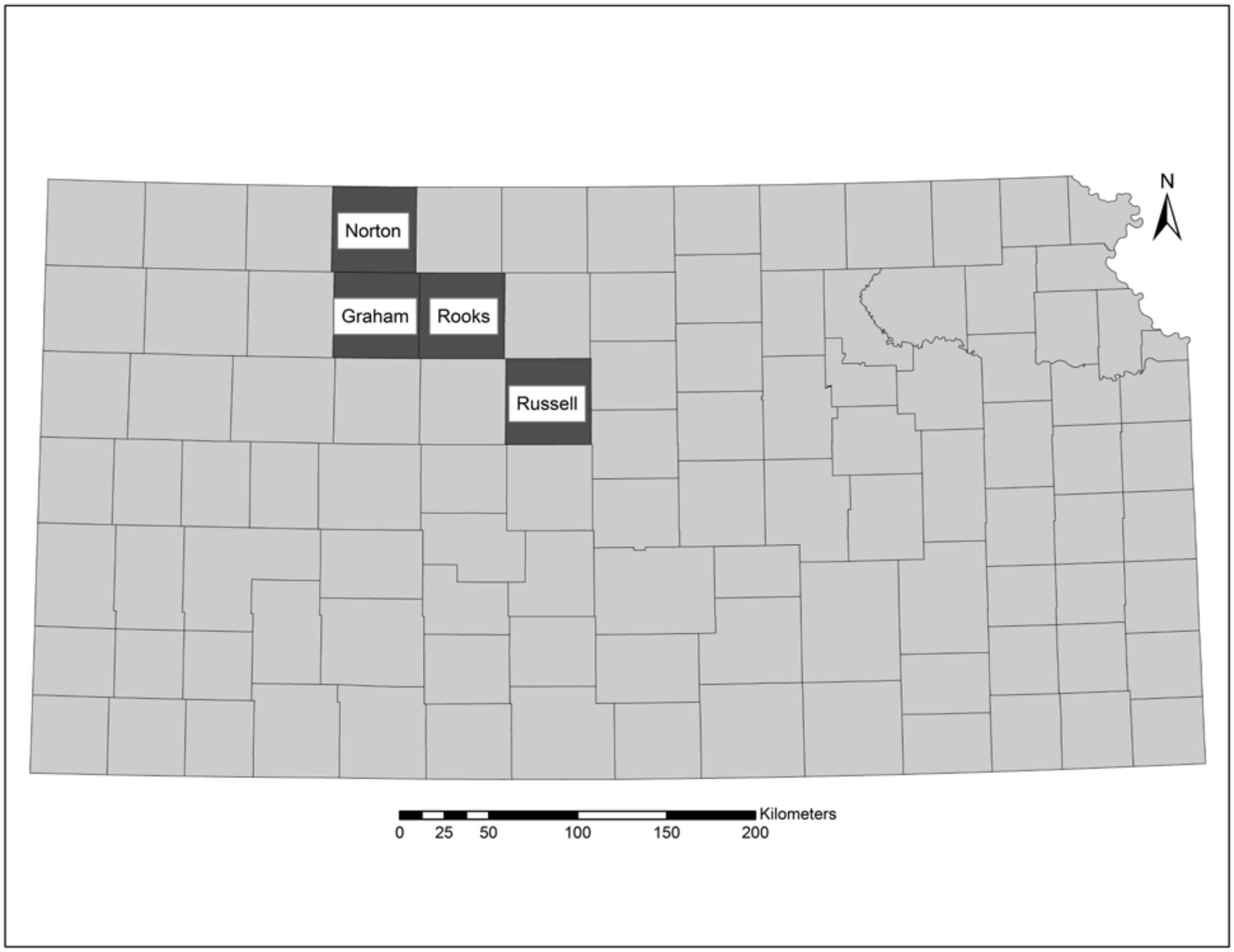

Figure 2.2. Kansas counties with the counties containing the study areas in 2017-2019, Graham, Norton, Rooks, and Russell, in dark grey.

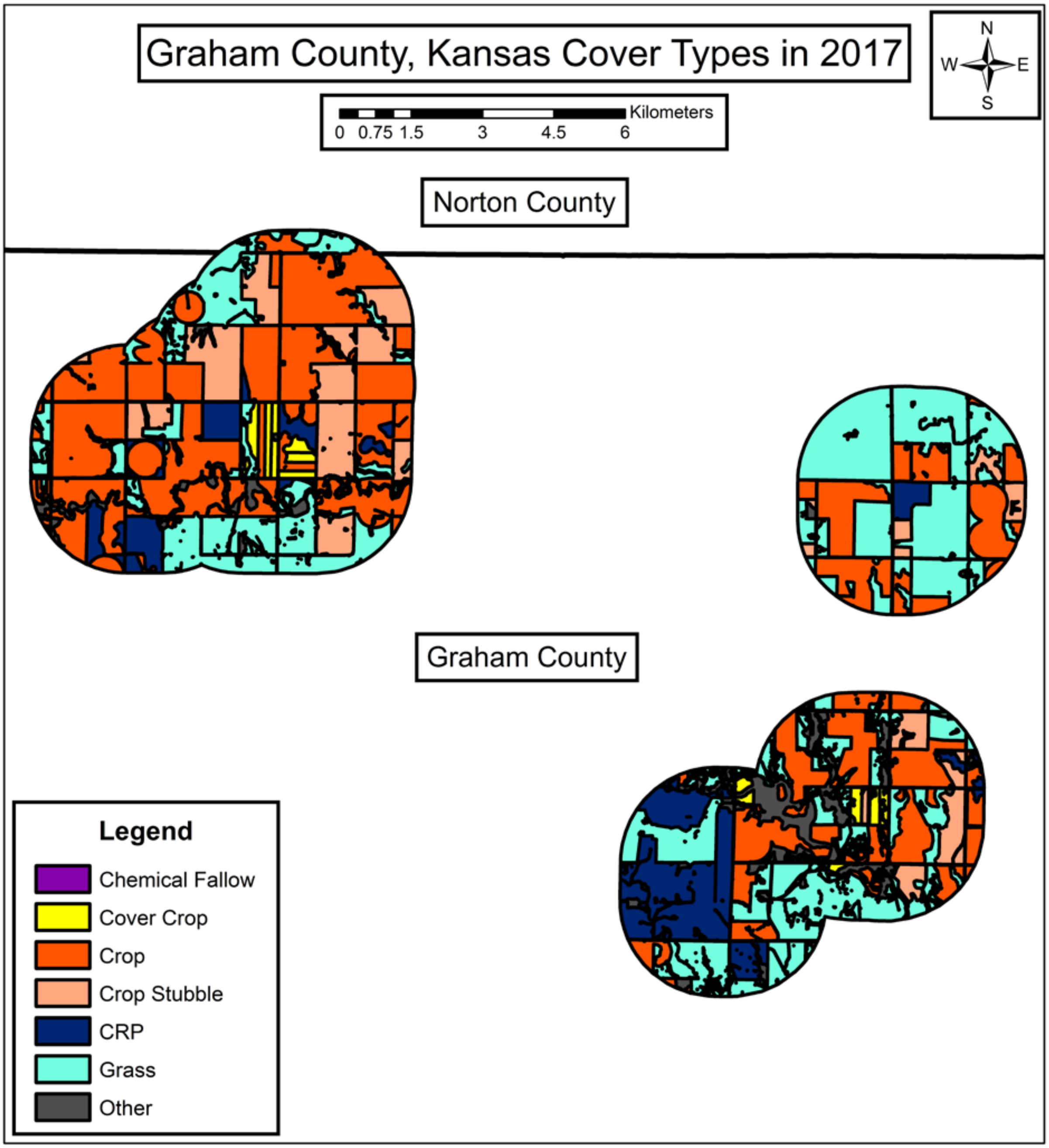

Figure 2.3. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2017 in Graham County, Kansas, USA.

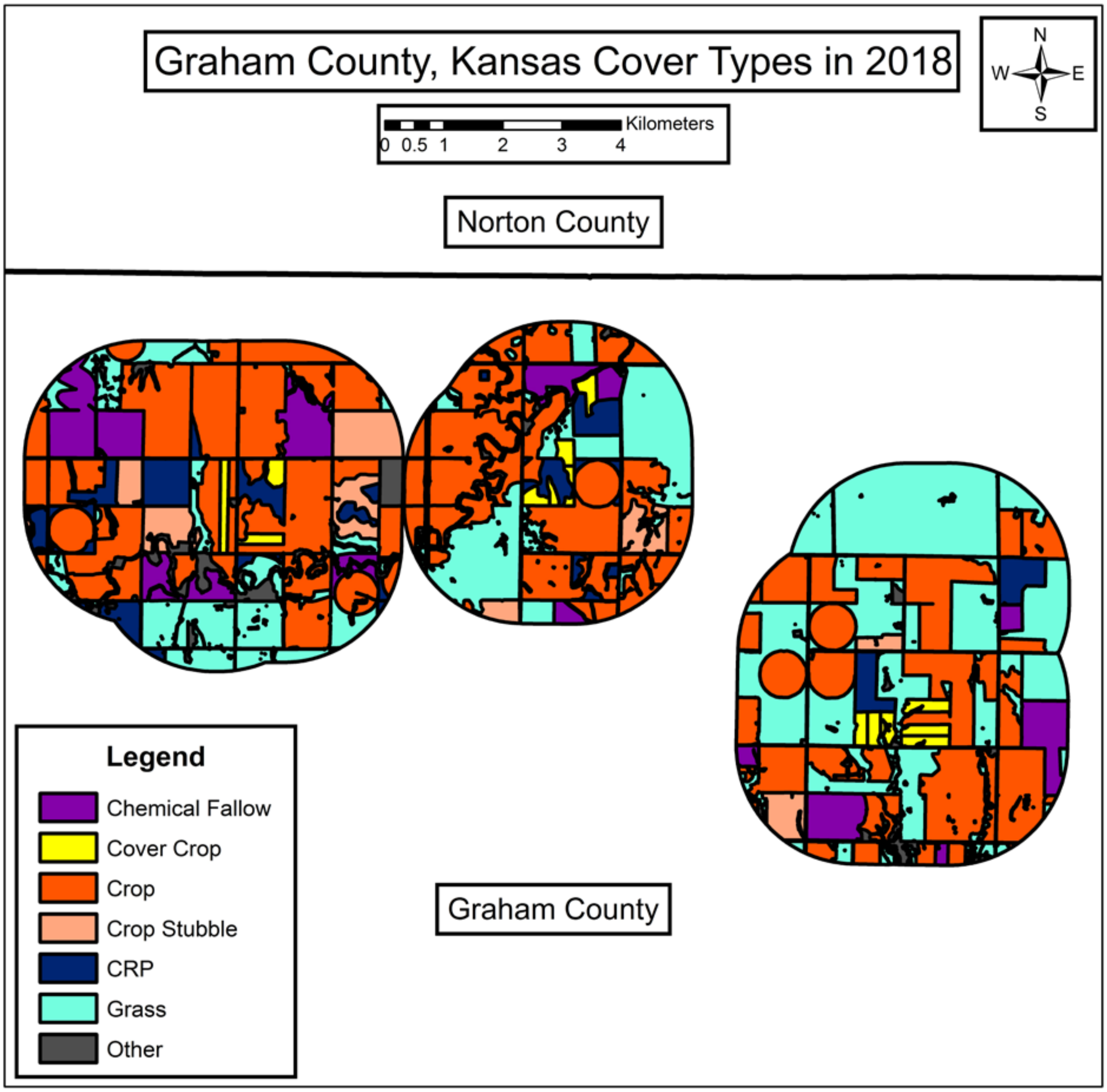

Figure 2.4. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Graham County, Kansas, USA.

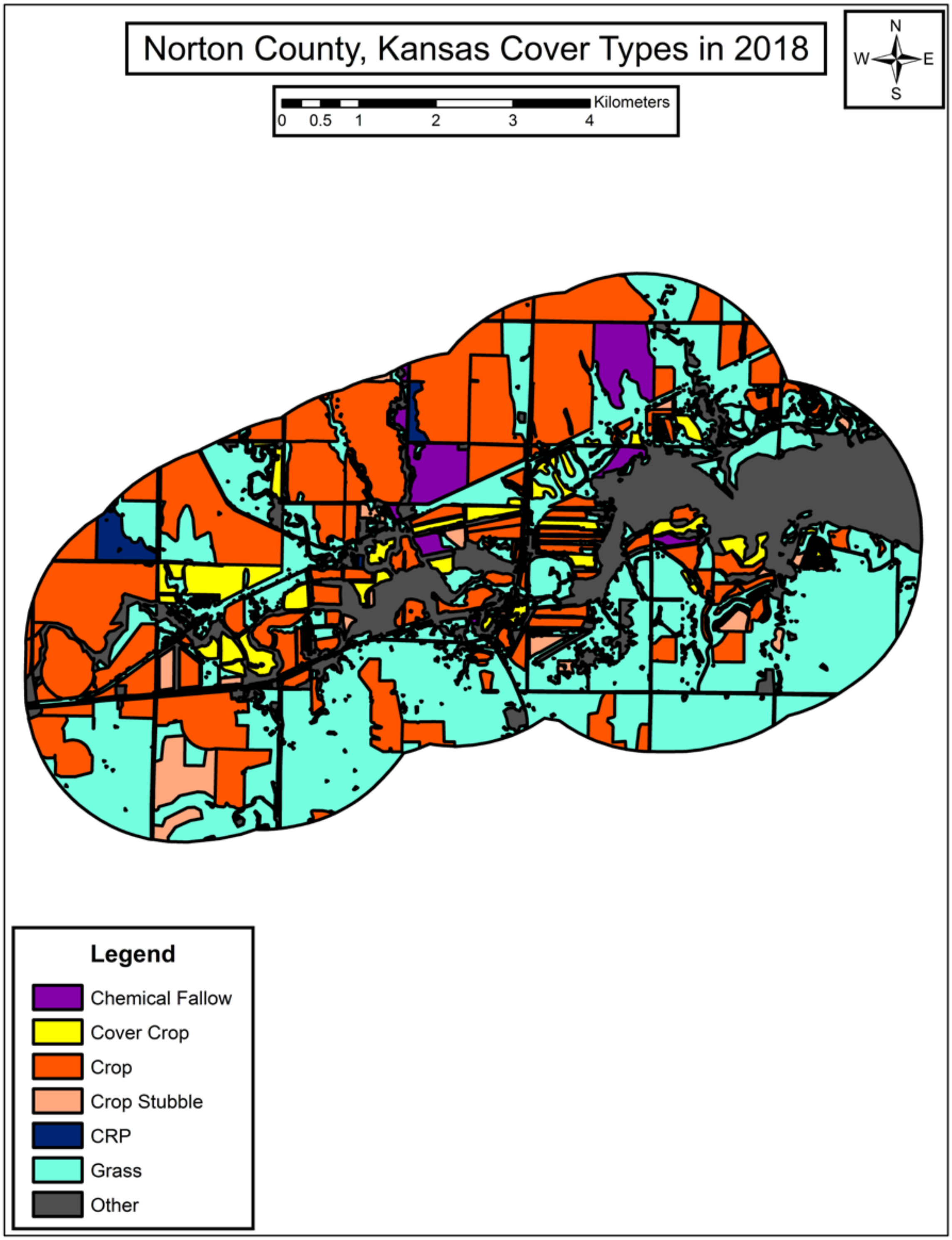

Figure 2.5. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Norton County, Kansas, USA.

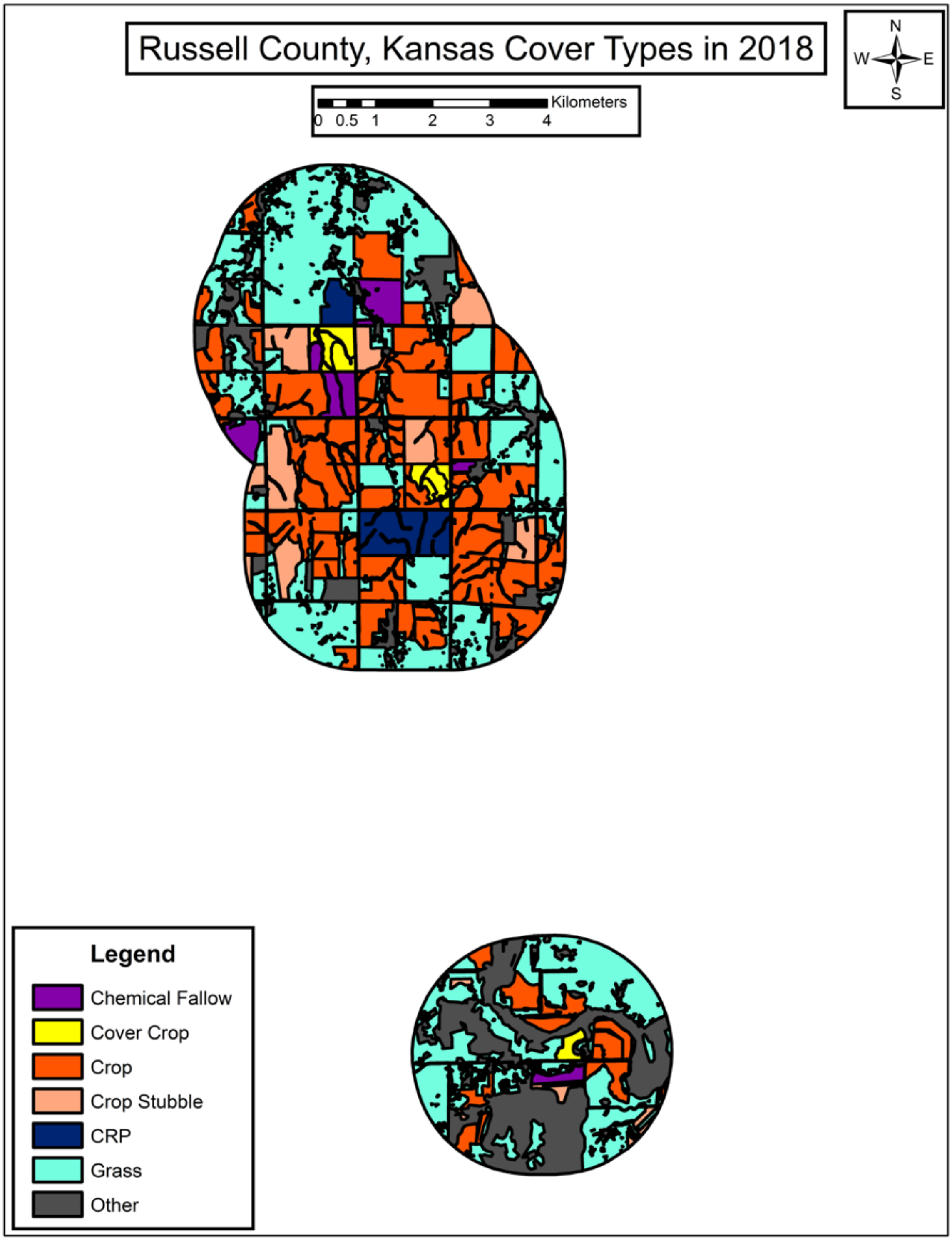

Figure 2.6. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Russell County, Kansas, USA.

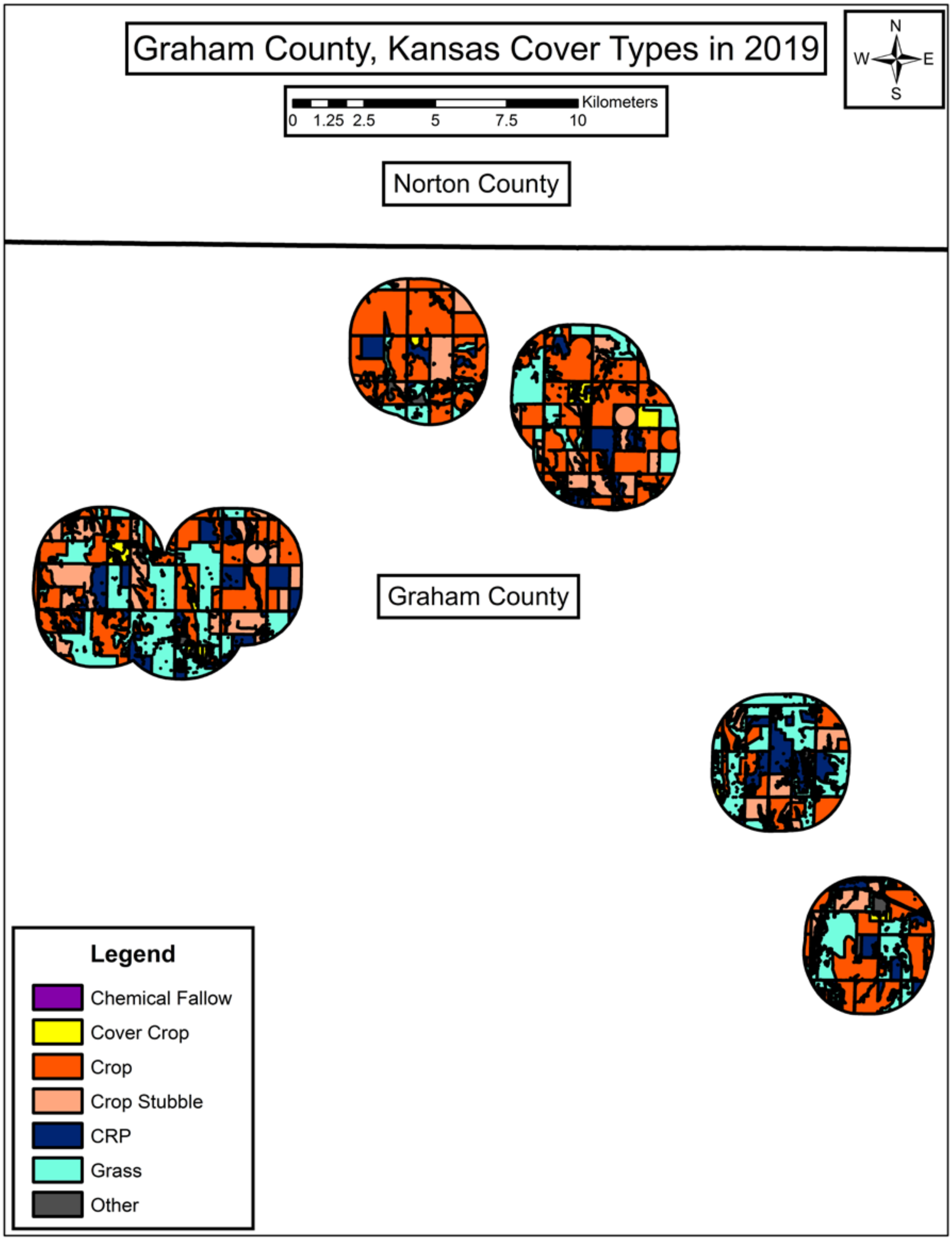

Figure 2.7. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Graham County, Kansas, USA.

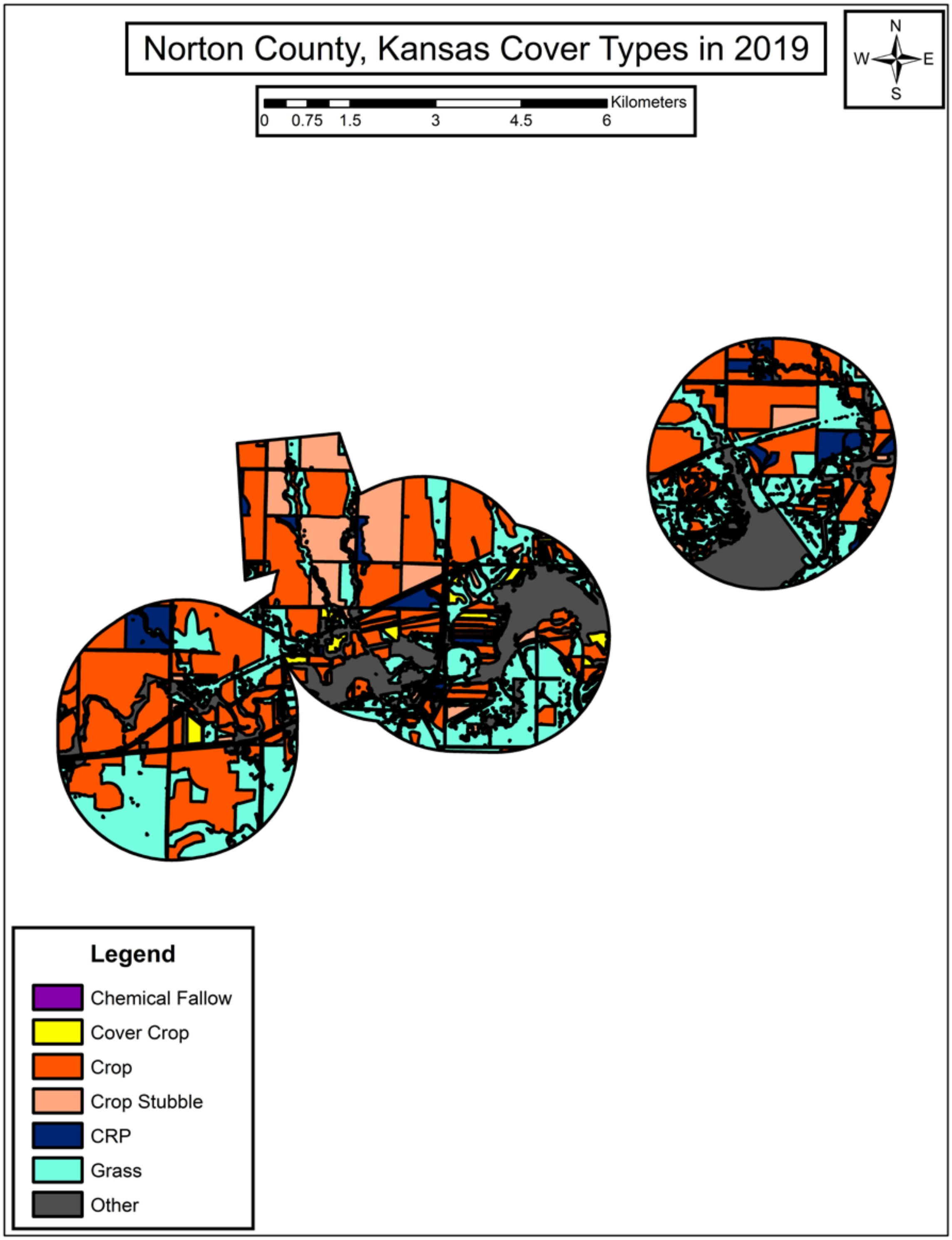

Figure 2.8. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Norton County, Kansas, USA.

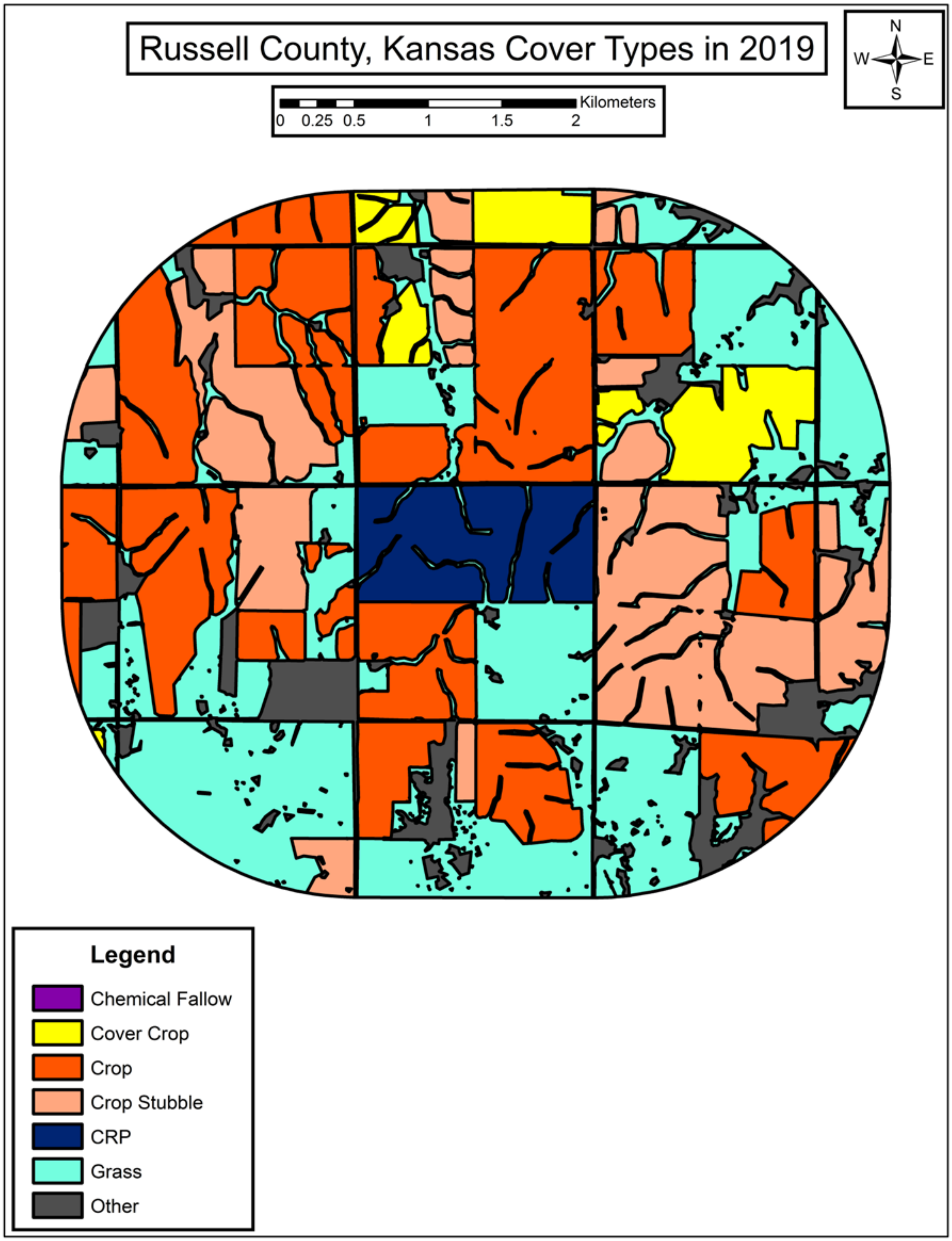

Figure 2.9. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Russell County, Kansas, USA.

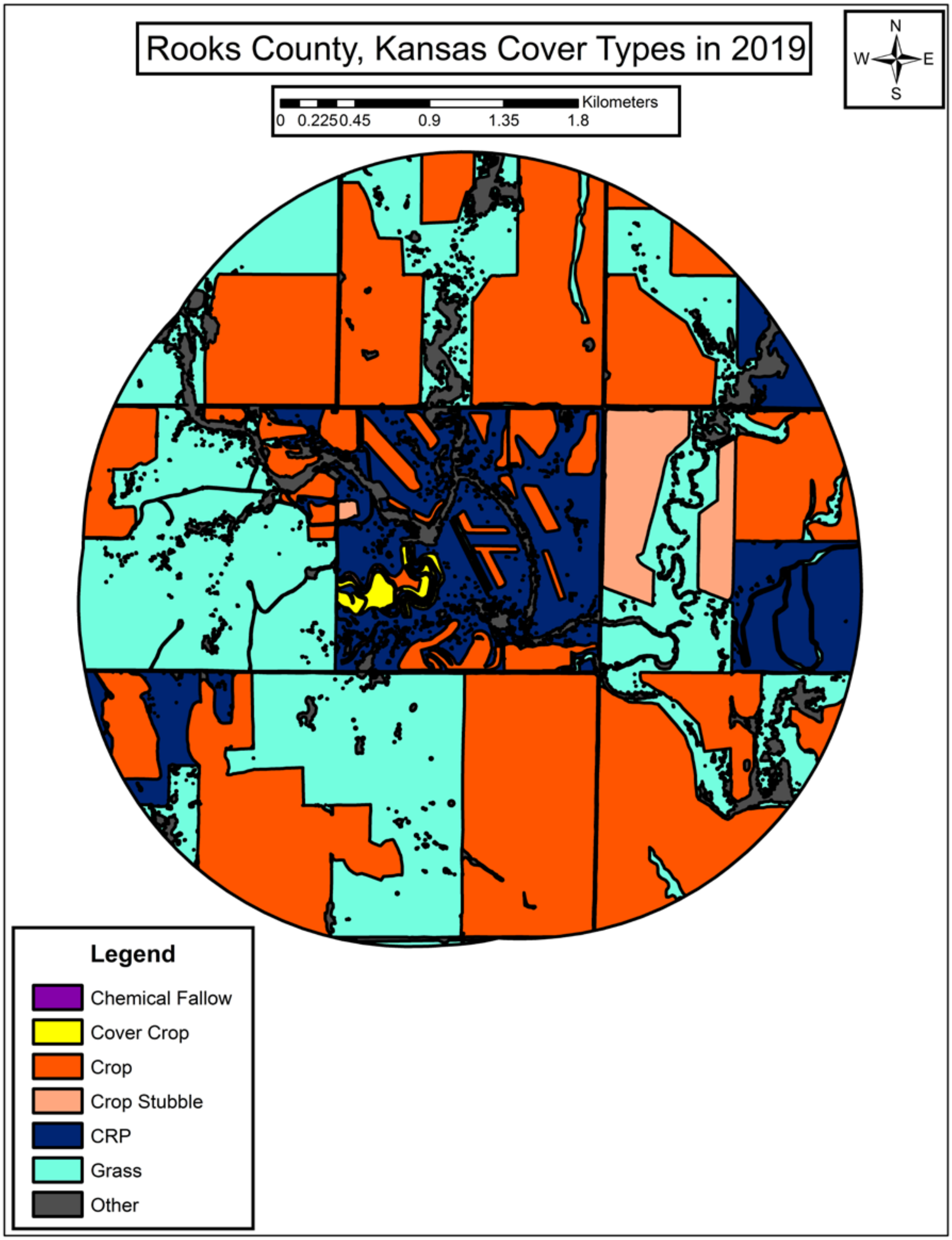

Figure 2.10. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Rooks County, Kansas, USA.

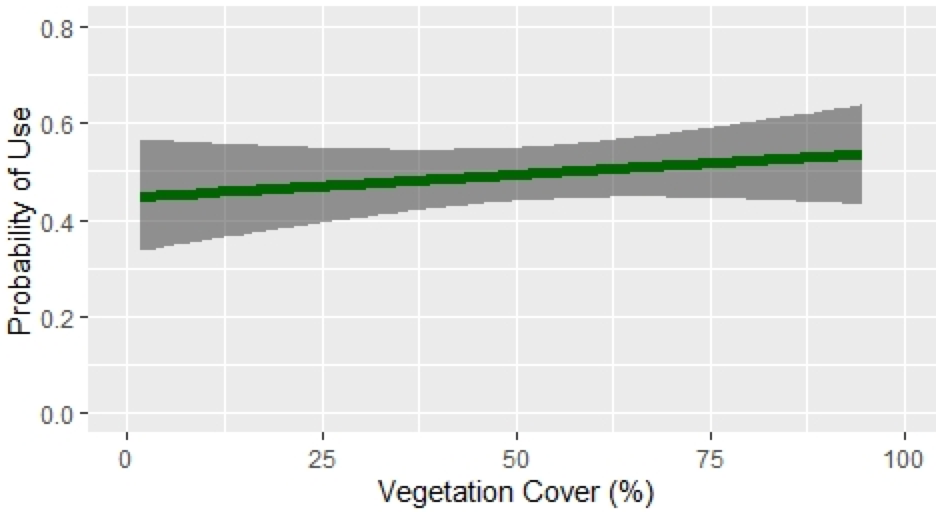

Figure 2.11. The probability of use by ring-necked pheasant (*Phasianus colchicus*) broods based on the average percent of vegetation (grass, forb and crop) cover, based on the resource selection model with the most support, comparing used to random locations (*n* = 364), in western Kansas, USA during 2017–2019.

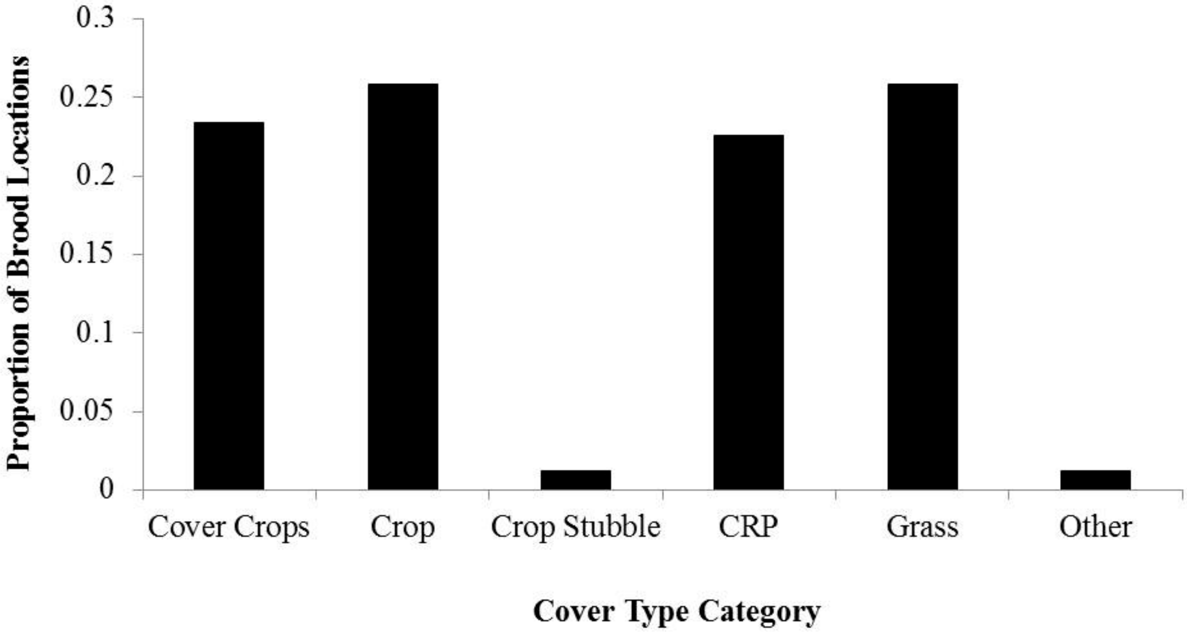

Figure 2.12. Cover type categories of triangulated ring-necked pheasant (*Phasianus colchicus*) brood locations during 2017–2019 in western Kansas (*n* = 244).

Table 2.1. Summary of climate, weather and land cover of study areas in western Kansas, from 2017–2019. Climate data includes long-term averages of annual precipitation totals (mm) and long-term averages of annual average temperature (°C), from 1981–2010 annual normal data at three weather stations (USW00093990-Graham and Rooks, USC00145852-Norton, USW00093997-Russell). Weather was collected at the same weather stations. Average temperature was calculated by adding the maximum temperature and minimum temperature and dividing by two. The study area land cover percentages were estimated from the project's cover type maps of the study areas from 2019. The other cover type includes trees, bodies of water, roads, and manmade objects.

	Graham	Norton	Rooks	Russell
Average Annual Temperature	11.9	11.0	11.9	12.6
Average Annual Total Precipitation	582.17	656.34	582.17	648.46
2017 Average Temperature	13.2	11.8	13.2	13.7
2018 Average Temperature	12.0	10.3	12.0	13.1
2019 Average Temperature	11.7	10.1	11.7	12.1
2017 Total Precipitation (mm)	590.0	325.2	590.0	439.6
2018 Total Precipitation (mm)	921.2	256.3	921.2	795.5
2019 Total Precipitation (mm)	744.7	322.8	744.7	692.8
Percent Crop	40	37	42	30
Percent Crop Stubble	13	7	3	18
Percent Cover Crop	2	1	1	5
Percent Grass	3	32	33	32
Percent CRP	12	3	15	5
Percent Other	30	20	6	10

Table 2.2. Summary of ring-necked pheasant (*Phasianus colchicus*) hens captured and outfitted with radio collars, nesting attempts monitored, nests hatched, and broods monitored in western Kansas, USA, 2017– 2019.

	Year		
Data Type	2017	2018	2019
Hens Captured	40	47	35
Nests Monitored	38	44	16
Nests Hatched	6	11	5
Broods Monitored	5	8	5

Table 2.3. Ring-necked pheasant (*Phasianus colchicus*) brood resource selection results for insect community collected using insect sweeps at used and random locations from 2017 – 2019 in western Kansas, USA (*n* = 364).

Model	AIC_c[a]	ΔAIC_c	$AIC_c\, w_i$	*K*
Hemiptera Count	505.74	0	0.19	2
Diptera Count	506.70	0.96	0.12	2
Lepidoptera Count	506.73	0.99	0.12	2
Orthoptera Count	508.23	2.49	0.05	2
Richness	508.33	2.59	0.05	2
Other Count	508.36	2.62	0.05	2
Total Count	508.45	2.71	0.05	2
Coleoptera Mass	508.53	2.79	0.05	2
Coleoptera Count	508.56	2.82	0.05	2
Other Mass	508.56	2.82	0.05	2
Lepidoptera Mass	508.6	2.86	0.05	2
Diptera Mass	508.63	2.89	0.05	2
Total Mass	508.63	2.89	0.05	2
Hemiptera Mass	508.63	2.89	0.04	2
Orthoptera Mass	508.63	2.89	0.04	2

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\, w_i$ - Akaike weights, *K*- number of parameters

Table 2.4. Average dry biomass (g) and counts (individuals) of 100-m insect sweep transects with standard errors comparing points used by ring-necked pheasant (*Phasianus colchicus*) broods (*n* = 183) to random points in the same cover type (*n* = 181) for the insect orders in the top models (<2 ΔAIC_c ; Table 2.3), from 2017–2019 in western Kansas, USA.

Order	Used $\bar{x}$ Dry Biomass(g)	Random $\bar{x}$ Dry Biomass(g)	Used $\bar{x}$ Count (Individuals)	Random $\bar{x}$ Count (Individuals)
Dipterans	0.0169 ± 0.0019	0.0210 ± 0.0024	22.45 ± 1.75	22.65 ± 1.84
Hemipterans	0.1595 ± 0.0251	0.1137 ± 0.0127	33.94 ± 3.42	33.71 ± 3.41
Lepidopterans	0.1102 ± 0.0133	0.1413 ± 0.0184	5.41 ± 0.63	5.59 ± 0.71

Table 2.5. Ring-necked pheasant (*Phasianus colchicus*) brood resource selection results for vegetation characteristics, of the top models (<2 ΔAIC_c) from two models suites for Visual Obstruction Readings and overhead composition, from 2017–2019 in western Kansas, USA.

	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	*K*
Average Percent Vegetation	437.12	0.00	0.39	2
Average Percent Litter	438.70	1.58	0.18	2
Average Percent Ground	438.98	1.86	0.15	2
Quadratic Average Vegetation	439.02	1.90	0.15	3
0% VOR	439.32	2.20	0.13	2

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, *K* - number of parameters

Table 2.6. Average point vegetation characteristics comparing points used by ring-necked pheasant (*Phasianus colchicus*) broods (n = 157) to random points in the same cover type (n = 159) in the top models (<2 ΔAIC_c; Table 5), from 2017–2019 in western Kansas, USA.

Vegetation Characteristics	Used $\bar{x}$	Random $\bar{x}$
Average Percent Vegetation	53.32 ± 2.16	50.56 ± 2.09
Average Percent Litter	29.20 ± 1.381	30.74 ± 1.43
Average Percent Ground	43.22 ± 2.03	44.79 ± 1.92
Average 0% VOR (dm)	7.83 ± 0.38	7.77 ± 0.37

Table 2.7. Average ring-necked pheasant (*Phasianus colchicus*) brood movement measurements (*n* = 18) from 2017–2019 in western Kansas, USA, including average distance moved from the nest location (m), maximum distance between brood locations within a brood (m), and maximum distance from the mean center of all brood locations for the individual brood and an individual location (m).

	Initial Distance Moved (m)	Maximum Distance Between Locations (m)	Maximum Distance From Mean Center (m)
Minimum	35	273	148
Mean	164	692	438
Median	145	672	399
Maximum	462	1348	1044
Standard Error	32	73	53

Chapter 3 - Patch and resource selection of ring-necked pheasant hens in Kansas

Introduction

Resources are distributed unevenly across the landscape (Leopold 1933, Manly et al. 2002, Scheiner and Willig 2011). Often, isolated patches known to contain a species are considered islands in a sea of inhospitable patches (Turner and Gardner 2015). Unlike true islands, characteristics of surrounding patches can strongly influence the population within a particular patch (Turner and Gardner 2015). Ring-necked pheasants (*Phasianus colchicus*; hereafter pheasant) are one of many species that maintain sustainable populations in agricultural landscapes. The typical agricultural landscape consists of large, homogeneous crop fields interspersed with other cover types. Wildlife occupying small patches among crop fields face increased edge effects, reduced connectivity, and possibly depressed habitat stability (Turner and Gardner 2015). The matrix of crop fields may influence dispersal capacity among habitat patches and possibly provide alternative habitat (Turner and Gardner 2015). To successfully manage wildlife populations within an intensive agricultural landscape, an understanding of their use of the landscape, movement among patches, and use of resources are required (Manly et al. 2002, Turner and Gardner 2015). Pheasants, a common resident of agricultural spaces offer a strong focal species to study the effects of the surrounding agricultural matrix on wildlife resource selection and determine how manipulating agricultural practices influence these selection patterns. Previous studies found pheasant hens with smaller home ranges had increased survival (Gatti et al. 1989, Perkins et al. 1997). Home range size may be related to habitat juxtaposition, with hens expanding their range in areas with poor habitat juxtaposition to meet all of their requirements (Applegate et al. 2002).

Since the addition of the U.S. Department of Agriculture Conservation Reserve Program (CRP) land to the pheasant range in 1986, researchers investigated the influence of CRP on pheasants during the breeding season. Under CRP, landowners receive assistance to convert highly-erodible cropland to grassland under potentially renewable 10-15 year contracts (Rodgers 1999, Eggebo et al. 2003). Pheasants responded to the addition of CRP patches by altering their movements and habitat use, which varies with patch age, seed mix, and within patch heterogeneity (Rodgers 1999, Eggebo et al. 2003). Male and young pheasants more commonly use older CRP fields and cool-season-legume mix fields compared to warm-season fields (Eggebo et al. 2003). Hens select CRP over other grasslands and other cover types for nesting and brood rearing in Nebraska (Matthews et al. 2012 a,b). Hen home ranges are smaller in areas with high CRP density (minimum convex polygon [MCP] = 68.87 ± 22.58 ha; adaptive kernel [ADK] = 127.05 ± 30.38 ha) compared to areas with low CRP density (MCP = 84.43 ± 19.83 ha; ADK = 155.26 ± 19.07 ha; Applegate et al. 2002). The addition of other potential habitat patches across the landscape may further affect space use and movement of pheasants.

Planting spring cover crops is one of the current management practices applied to increase pheasant nesting and brood-rearing habitat in agricultural landscapes. Current declining populations across the Midwest have increased the demand for alternative management strategies (Flake et al. 2012). Anecdotally, managers consider spring cover crops as a practice to boost local pheasant recruitment rates while providing agricultural benefits by converting fallow fields to green fields during the breeding season. The typical crop rotation practice in western Kansas, is use of herbicides to control vegetation in fields left fallow after corn (Zea mays) or grain sorghum (Sorghum bicolor) harvest in the fall until winter wheat (Triticum sp.) is planted the following fall (~12-14 months). Nesting and brood-rearing efforts for pheasants and other wildlife fall within the period when the field is fallow. Alternatively, by planting spring cover crops in March or April, producers benefit from increased organic matter, nitrogen fixing, soil nutrient movement and reduced weeds, and reduced soil compaction and erosion (Villami et al. 2006, Wayman et al. 2014, Ladoni et al. 2016). Addition of spring cover crops to landscapes has the potential to alter pheasant home ranges, movements, and influence other aspects of their life history, which is important information for managers promoting pheasant population growth in an agriculturally dominated landscape.

Wildlife, including pheasants, may benefit from the additional cover and food resources provided by spring cover crops during breeding (Jeliazkov et al. 2016, KDWPT 2016, Wilcoxen et al. 2018). Many spring cover crop seed mixes contain small grains, which pheasants use as nesting and brood-rearing sites (Warner 1979, Flake et al. 2012, Wilcoxen et al. 2018). Other mixes contain a wide variety of forbs, which attract invertebrates, providing additional food resources for broods. Producers can select mixes to potentially provide nesting habitat, brooding habitat, or both (KDWPT 2016, Wilcoxen et al. 2018). Seed companies have commonly developed commercial mixes, but will often create custom mixes of varying complexity by request. Simple mixes can contain two plant species, whereas more complex blends can contain approximately a dozen species. Though considered beneficial for most wildlife species by decreasing homogeneity of agricultural landscapes (Jeliazkov et al. 2016), wildlife responses to different blends are relatively undocumented. Bird diversity increases in cover crop fields compared to fallow fields, but mechanisms driving this difference are unknown, limiting the potential to maximize wildlife benefits (Wilcoxen et al. 2018).

In order for spring cover crops to be an effective pheasant population management strategy, pheasants must find and use cover crops. Understanding how pheasants utilize the landscape, including cover crops, will help focus management efforts. My research objectives were to (1) measure movements and space use by pheasant hens among potential habitat patches within a landscape dominated by row-crop agriculture, (2) test resource selection of vegetation composition and structure by pheasant hens, and (3) determine pheasant hen use and selection of three different spring cover crops blends relative to a chemical fallow control.

Study Areas

I researched pheasants in two ecoregions of Kansas during the 2017–2019 breeding seasons: High Plains (Graham and Norton counties) and Smoky Hills (Rooks and Russell counties; Fig. 3.1). Counties were dominated by cropland and interspersed with Conservation Reserve Program (CRP) land and native grassland (National Soil Cooperative 1977; 1982a,b; 1986). Wheat (Triticum sp.) is the primary cash crop in both ecoregions, with >50% of the cropland planted to wheat. The remaining cropland consisting of corn, grain sorghum, soybeans (Glycine max), and fallow areas (National Soil Cooperative 1977; 1982a,b; 1986). The typical crop rotation consists of corn or grain sorghum and a 12-14-month fallow period followed by winter wheat (Roozeboom et al. 2009, KDWPT 2016).

The High Plains consists of short-grass prairie with mixed- and western tall-grass prairies (Lauver et al. 1999). The short-grass prairie is dominated by blue grama (Bouteloua gracilis) and buffalograss (B. dactyloides) with scattered purple threeawn (Aristida purpurea), broom snakeweed (Gutierrezia sarothrae), slimflower scurfpea (Psoralidium tenuiflorum), and upright prairie coneflower (Ratibida columnifera; Lauver et al. 1999). The western tall-grass prairie, in the High Plains, is predominantly comprised of big bluestem (Andropogon gerardii) and indian grass (Sorghastrum nutans) with intermixed Illinois bundleflower (Desmanthus illinoensis), American licorice (Glycyrrhiza lepidota), switchgrass (Panicum virgatum), western wheatgrass (Pascophyrum smithii), common threesquare (Schoenoplectus pungens), and sand dropseed (Sporobolus cryptandrus; Lauver et al. 1999).

In the Smoky Hills, the Dakota Hills tall-grass prairie is comprised mainly of big bluestem, switchgrass, little bluestem (Schizachyrium scoparium), with sideoats grama (Bouteloua curtipendula), Fremont's clematis (Clematis fremontii), indian grass, prairie spiderwort (Tradescantia occidentalis), and Tharp's spiderwort (Tradescantia tharpii; Lauver et al. 1999). The mixed-grass prairie in both regions is dominated by little bluestem, sideoats grama, and blue grama (Bouteloua gracilis) with ragweed (Ambrosia psilostachya), big bluestem, groundplum milkvetch (Astragalus crassicarpus var. crassicarpus), hairy grama (Bouteloua hirsuta), buffalograss, yellow sundrops (Calylophus serrulatus), nineanther prairie clover (Dalea enneandra), blazing star (Liatris punctate), and Indian grass (Lauver et al. 1999).

I defined the study areas within each county as 2 km around fields where I successfully captured pheasants and 2 km around cover crop treatment fields, which comprised a different portion of the study (Figs. 3.2 – 3.9). In 2017, the study area consisted of 9,945 ha in Graham County. In 2018, I expanded into Russell and Norton counties (19,939 ha). The Norton County study areas were located on the Norton State Wildlife Management Area; all other study areas were on private land. In 2019, I added one study area in Rooks County while continuing research in the first three counties (22,958 ha). Annual long-term average precipitation and temperature were similar among counties (Table 3.1). Percent crop coverage was similar among counties. Graham County had 3 percent native grass coverage compared to around 30% in the other counties, but did have the second most amount of CRP coverage (Table 3.1). The number of treatments fields per county varied by year (Table 3.2) with the most treatments occurring in 2019. The number of fields planted varied annually (Table 3.2).

Methods

Treatment Fields

I collaborated with landowners in western Kansas to plant spring cover crop treatment fields in landscapes supporting pheasants during 2017–2019 (n = 13). Fields were in rotation for fall planting of winter wheat after a grain crop (corn or grain sorghum). Each study field was ~65 ha (quarter section; 120 acres), located adjacent to Conservation Reserve Program land and divided equally into four treatment plots (~17 ha), three spring cover crop mixes and a chemical fallow control. Treatments were randomly assigned to each plot within the field. Cover crops were planted in mid-March to mid-April, with chemical termination of cover crops in late June or July to be in compliance with crop insurance requirements. Treatment fields covered 1,192.1 ha across years, with 213.3 ha in chemical fallow, 322.8 ha in Chick Magnet, 334.6 ha in custom mix, and 321.4 ha in GreenSpring (Table 3.2).

Seed Mixes

Three cover crop seed mixes were selected for this study including GreenSpring© (73 kg/ha), Chick Magnet© (28 kg/ha), and a Custom Wildlife Mix (41 kg/ha). GreenSpring© is a common mix developed by Star Seed Company (Osbourne, KS, USA) for its agricultural benefits and potential to hay the crop for use as cattle feed. The mix contained cool-season peas (Pisum sativum) and oats (Avena sativa). Chick Magnet© was designed by Star Seed Company for precocial gamebird chicks. The mix contains warm-season, broad-leafed forbs that offer extensive overhead concealment with sparse stems for easy movement for the chicks. Species included in the mix were: cowpeas (Vigna unguiculata), cool-season peas, yellow sweet clover (Melilotus officinalis), hybrid brassica (Brassica spp.), sunflower (Helianthus spp.), and buckwheat (Fagopyrum esculentum). The final mix was a custom mix designed by Star Seed

Company and Kansas Department of Wildlife, Parks, and Tourism to be adaptive to different climatic conditions and provide a variety of resources for wildlife. Species included were chickling vetch (Vicia villosa), radish (Raphanus raphanistrum), oats, cool-season peas, rapeseed (Brassica napus), sunflowers (Helianthus spp.), turnips (Brassica rapa), and yellow sweet clover. I also had a chemical fallow control treatment as a control where nothing was planted and landowner used herbicide to prevent weed encroachment into the field. This treatment represented the standard agriculture practice in the absence of planting spring cover crops.

Data Collection

Capture- Pheasant capture efforts were concentrated in CRP and native-grass fields within 2 km surrounding study fields to maximize the probability that treatment fields were available for use by all tagged pheasants. I used a combination of nightlighting (Gatti et al. 1989, Gabbert et al. 1999, Applegate et al. 2002, Flock and Applegate 2002) and baited air cannon to capture pheasant hens from early February to April 15, 2017–2019. Nightlighting required a team of five, including a driver, two netters, and two spot-lighters. I systematically searched CRP fields with a specially equipped vehicle at night, with a zig-zag pattern, for pheasants moving from the disturbance. Spot lighters shined their lights to confuse the birds and keep them on the ground while the netters used salmon nets to capture birds. Efforts were limited to calm nights (winds <16 kmph) with high relative humidity (>60%) to minimize fire risk. No trapping occurred during rain events for the safety of the birds. I fitted captured hens with a 15-g necklace-style very-high-frequency (VHF) transmitter with an 8-hr mortality switch (Model #A3960, Advanced Telemetry Systems, Inc., Isanti, MN, USA) and a unique numbered aluminum leg band (Draycott et al. 2006). I measured morphological features of captured birds including sex based on plumage characteristics, mass determined by a spring scale (g), flattened wing chord length (cm), and tarsus length (mm). Birds were released at the capture site after approximately 10 minutes of handling. Procedures followed the guidelines for handling wild animals required by the Kansas State University (KSU) Institutional Animal Care and Use Committee (IACUC #3831) and State of Kansas Scientific, Education, or Exhibition Wildlife Permits (SC-018-2017, SC-024-2018, and SC-015-2019).

Monitoring- Radio-collared individuals were monitored a minimum of twice a week (usually >4) from capture through September to monitor through nesting, brood rearing, and brood break-up period. Hens were monitored during three daily time periods: morning foraging, loafing, and evening foraging. Foraging locations occur from sunrise to two hours after sunrise and two hours before sunset to sunset. Loafing locations were defined as between the two foraging time periods, starting two hours after sunrise and ending two hours before sunset. Foraging locations will capture important crepuscular movements, which differ from diurnal movements (Gatti et al. 1989). Locations were determined using a handheld telemetry system, with a three-element yagi antenna and a handheld radio receiver (Communication Specialists, Inc. Orange, CA, USA), to triangulate the location of each individual. I used Location of a Signal software to estimate error polygons and continued taking bearings until three bearings were taken within 20 minutes and estimated an error polygon ≤2,000 m2 (Ecological Software Solutions 2010).

Vegetation Surveys- At least 2 locations were randomly selected per week per tagged hen for vegetation surveys. I measured vegetation at the location and a random paired location within 300 m in the same patch to assess within patch or point-scale selection (i.e., 4th order selection; Johnson 1980). I used composition surveys to measure the percent cover of bare ground, litter, forbs, warm-season grasses, cool-season grasses, woody species greater and less than 1.5 m tall, crop, and standing crop stubble within a 60-cm Daubenmire frame at each point and 4 m to the north, south, east, and west of the point (Daubenmire 1959). Litter (unrooted, dead vegetation) depth (cm) was measured in the northeast corner of the frame. I used visual obstruction surveys to measure the highest dm with 100%, 75%, 50%, 25% and 0% visual obstruction of the Robel pole from each cardinal direction at 4 m away from the point at 1 m above ground (Robel et al. 1970). I estimated an index to overhead cover by subtracting the light intensity (kLux) at ground level from the light intensity at 1 m above ground to determine the light blocked by vegetation (Extech® EasyView Light Meter, Extech Instruments, Nashua, NH, USA).

Cover Map- I developed a land cover map by classifying each study area within 2 km of CRP fields and cover crop treatment fields into land use categories including: cover crop seed mix, growing corn, growing milo, crop stubble, wheat stubble, CRP/grassland, green wheat and other. I used National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery to delineate boundaries between land cover categories. Then, I confirmed delineations with on-the-ground visits.

Statistical Analysis

I generated 95% kernel density home range estimates for all birds with 25 triangulated locations from May 15 to August 15 with nest locations counting as a singular location (n = 55). The 95% Kernel Density hen home ranges were generated in Program R, version 3.4.1, using the adehabitatHR package. I compared location cover types to the home range cover types and the home range cover types to the cover types within 1 km of the field of capture to estimate selection rankings and selection ratios for cover types (Manly et al. 2002). I generated selection rankings and ratios using the compositional analysis in the adehabitatHS package in Program R (Aebischer et al. 1993, Calenge 2006). I pooled data across years.

I compared locations used by pheasants to random locations using two techniques. First, I used a multivariate analysis of variance to compare vegetation among use and random points, the three temporal location types, patch type, and their interactions. Next, I used Resource Selection Functions to determine the relative influence of vegetation variables on space use by hens (Keating and Cherry 2004). Triangulated locations were assigned a “1” for used and random locations were assigned a “0” in a logistic regression framework. I used Akaike’s information criterion for small sample sizes (AICc) to assess model performance (Anderson et al. 2000, Anderson 2008). Visual obstruction readings (VOR) and other vegetation characteristics were compared in separate model suites. Competing models (<2 ΔAICc) within each model suite were combined and compared in a final model suite (Anderson et al. 2000, Anderson 2008). The VOR model suite contained 10 models: 0% VOR, 25% VOR, 50% VOR, 75% VOR, 100% VOR, quadratic 0% VOR, quadratic 25% VOR, quadratic 50% VOR, quadratic 75% VOR, and quadratic 100% VOR. The composition model suite contained 14 models: average percent grass, average percent forb, average percent vegetation (grass + forb + crop), average overhead cover (light interception difference), average percent bare ground, average percent ground (bare ground + litter), average percent litter, quadratic average percent grass, quadratic average percent forb, quadratic average percent vegetation (grass + forb + crop), quadratic average over head cover (light difference), quadratic average percent bare ground, quadratic average percent ground (bare ground + litter), and quadratic average percent litter.

Results

I captured 119 hens over the duration of the study. Fifty-five hens had enough locations to estimate a home range using 2,849 locations. Forty home ranges were in Graham County, nine in Norton County, four in Russell County, and two in Rooks County. I conducted 1,633 vegetation surveys on used locations and random locations.

Average home range area across the breeding season was small (91.05 ha, SE = 14.43, n = 55) and hens showed minimal movements away from the mean center of the home range (Table 3.3). Exploratory movements, the maximum distance of a location to the mean center of the home range, averaged <1 km. Movements appeared to be based out of CRP fields, with limited exploratory movements. A circle with a radius of 1 km has an area of approximately 314 ha, considerably larger than the average home range area. The farthest distance between two locations of a hen was <1.5 km and less than the exploratory movements doubled.

Pheasant hens selected for CRP at second ($\lambda = 0.203$, $P = 0.001$) and third order ($\lambda = 0.204$, $P = 0.015$) selections levels (Figs. 3.10, 3.11). Though selection was consistent for CRP, when locations were sorted by cover type and week of the breeding season, hens do select other cover types as well (Fig. 3.12; Fig. 3.13). For example, use of wheat fields slowly increased until harvested in late June and early July when pheasants decreased use of these cover type. CRP remained the most used cover type in every week while other patches showed increases or decreases across the breeding season. Pheasants selected against crop stubble (Figs. 3.10, 3.11). All of the blends were highly ranked (Fig. 3.10) and had selection overlapping or greater than one for the home range to field scale (Fig. 3.11). Of the three cover crop blends, Chick Magnet had the lowest selection ratios (Fig. 3.11). When locations for the three different time periods were compared to the home range, there were similar patterns. GreenSpring had the highest selection rankings and greatest selection ratios of the cover crop blends among all time periods (Fig. 3.14, 3.15). Selection ratios for CRP and growing crop barely changed among time periods (Fig. 3.15). Wheat fields had the highest selection ranking during loafing (Fig. 3.13). Chick

Magnet was ranked similarly to crop stubble and had lower selection ratios than crop stubble (Figs. 3.14, 3.15).

Vegetation at used and available points was not different. For visual obstruction readings (0%, 25%, 50%, 75%, and 100% VOR), used and unused points were not different (Wilks λ = 0.999, $F_{1,1976}$ = 0.42, P = 0.83) but visual obstruction readings did vary by patch type (Wilks λ = 0.352, $F_{12,1976}$ = 37.58, P < 0.0001). Daubenmire frame measurements (average percent grass, average percent forb, average percent vegetation, average percent bare ground, average percent ground [bare ground and litter], and average overhead cover) showed the same pattern. Used and unused points were not different (Wilks λ = 0.995, $F_{1,1044}$ = 0.96, P = 0.45) but visual obstruction readings did vary by patch type (Wilks λ = 0.071, $F_{12,1044}$ = 49.19, P < 0.0001). There was a significant interaction between patch type and hen location type for both visual obstruction measurements (Wilks λ = 0.921, $F_{21,1930}$ = 1.53, P = 0.0004) and Daubenmire frame measurements (Wilks λ = 0.848, $F_{12,1044}$ = 1.45, P = 0.001).

Vegetation characteristics, when all locations were pooled and separated by morning foraging, evening foraging, and loafing locations, indicated hens selected locations based on vegetation height and cover (Tables 3.4 – 3.7). None of the effects were significant ($P \geq 0.05$). When all points were pooled, hens selected locations with relatively taller vegetation, with a positive relationship between the 0% VOR and hen use ($\beta = 0.001 \pm 0.009$ [SE], P = 0.94; Table 3.4; Fig. 3.16).

The time periods showed different patterns in selection, though none of it was significant ($P \geq 0.05$). Loafing locations had a negative relationship between the 0% VOR and hen use (β = -0.001 $\pm$ 0.011, P = 0.95; Fig. 3.17). Hens selected for bare ground ($\beta = 0.002 \pm 0.004$, P = 0.58) and vegetation (crop, grass, and forb coverage; $\beta = 0.00001 \pm 0.0025$, P = 0.98; Table 3.5).

Morning foraging locations were selected based on overhead cover, with use peaking around 45 kLux (Fig. 3.18). Hens also selected for taller vegetation (β = 0.011 ± 0.023, $P = 0.62$) and more overhead cover (β = 0.001 ± 0.004, $P = 0.85$; Table 3.6). Evening foraging locations selected for shorter vegetation (β = -0.011 ± 0.025, $P = 0.66$; Fig. 3.19), more forbs (β = 0.010 ± 0.012, $P = 0.39$), more bare ground (β = 0.003 ± 0.007, $P = 0.62$), more vegetation (β = 0.002 ± 0.005, $P = 0.65$), less litter (β = -0.005 ± 0.007, $P = 0.48$), less overhead cover (β = -0.002 ± 0.004, $P = 0.74$), less grass (β = -0.001 ± 0.004, $P = 0.81$) and less ground (β = -0.001 ± 0.005, $P = 0.88$; Table 3.7). Most of the models indicate that general cover or vegetation height were more reliable indicators of use than specific types of vegetation

Discussion

Hens appear to adjust their behavior in accordance with the changing landscape, shifting use among patches as resource availability changes during the growing season. Resources available within patches change with the breeding season due to vegetation succession (Manly et al. 2002). Hens are initially selecting for patch types that are likely to meet their resource requirements. Hens did select for different cover types but there were no significant relationships between point vegetation and pheasant use. Pheasant hens moved selectively among cover types and movements were limited.

Pheasant movements (1246.6 m ± 536.4) and home ranges (91.05 ha ± 14.43) were small. Previous home range estimates were from different time periods and not comparable to my home range estimates. In Iowa, spring minimum convex polygon (MCP) home ranges (April 1 – June 3) were 36.6 ha (± 11.9) and 47.7 ha (± 18.9) for two groups of hens (Schmitz and Clark 1999). Kansas MCPs from January to September were larger at 68.87 ha (± 22.58) and 84.43 ha (± 19.83) in areas with low and high CRP density (Applegate et al. 2002). Spring and breeding season MCP estimates were larger than winter MCP estimates in Wisconsin (32.0 ha; November – April; Gatti et al. 1989) and South Dakota (17.8 ha ± 2.9; December 1 – March 15; Gabbert et al. 1999). Other studies found that hens with smaller home ranges tend to have greater survival rates and suggest increasing landscape heterogeneity to minimize movements by hens may increase survival (Gatti et al. 1989, Perkins et al. 1997). Hens showed strong selection for CRP within their home ranges but were not confined within CRP boundaries and used cover crops and active crop fields in addition to CRP. The consistent use of CRP across the breeding season, while hens shifted use of other cover types, may indicate that CRP fields are crowded and some hens select alternative areas with less competition.

The cover crop mixes were different from each other and other cover types on the landscape in terms of vegetation and invertebrate community. Chick Magnet, the warm-season forb-only mix, ranked close to crop stubble for a number of vegetation and invertebrate measurements (Chapter IV). The mixes containing grass and forb species showed greater selection than Chick Magnet and more closely resembled CRP vegetation and invertebrate measurements. Pheasant selection of spring cover crops consistently ranked higher than crop stubble fields. Vegetation and invertebrate requirements for hens during the breeding season who are not nesting or brood-rearing remains unknown. I found no point scale research for non-breeding hens in peer-reviewed literature. Patch scale comparisons yielded significant results, but fail to determine the features of these patches pheasants select.

Despite the numerous scales considered, pheasant selection appears to be variable. Pheasant selection may operate on a different time scale than the breeding season and instead respond to agricultural practices. Winter wheat, as the dominant crop, has the most potential to impact pheasant selection. Pheasants use wheat for nesting, brood-rearing and cover (Warner

1979, Flake et al. 2012, KDWPT 2018). Wheat was ranked second for the number of observed nesting attempts (Chapter I). However, over the course of the breeding season, cover crops are planted mid-April and germinate in mid-May, grain sorghum is planted in June, cover crops are terminated in June and wheat is harvested in early July. All of these practices alter the resources provided by the fields. Within weeks, wheat harvest converts 1.5 m tall fields of dense wheat to stubble of variable height. The disturbance of the combines paired with the landscape change could influence pheasant spatial and resource selection, dividing selection into pre-harvest and post-harvest time periods.

Management implications

Pheasants select against crop stubble and for cover crop mixes that contain both grass and forb species. Producers are often prohibited from adding cover crops to their rotation because of a high initial investment in seed and equipment that takes years to recover through increased harvest profit. Initiating financial programs, as many state and federal agencies and nongovernment organizations have implemented, to help offset costs during the establishment of cover crops will allow more farmers to incorporate cover crops into their rotations. Providing access to demonstration fields through workshops and other learning opportunities in addition to information on example seed mixes and their benefits for the farmer and local wildlife is important to convince farmers to utilize cover crops. A gradual transition over to spring cover crops, with a starting goal of 5% of the landscape, will help limit financial strain for landowners and supporting agencies. Instead of focusing cover crops around a habitat patch, distributing cover crop fields randomly across the landscape will also support dispersing pheasants and pheasants in lower quality habitats.

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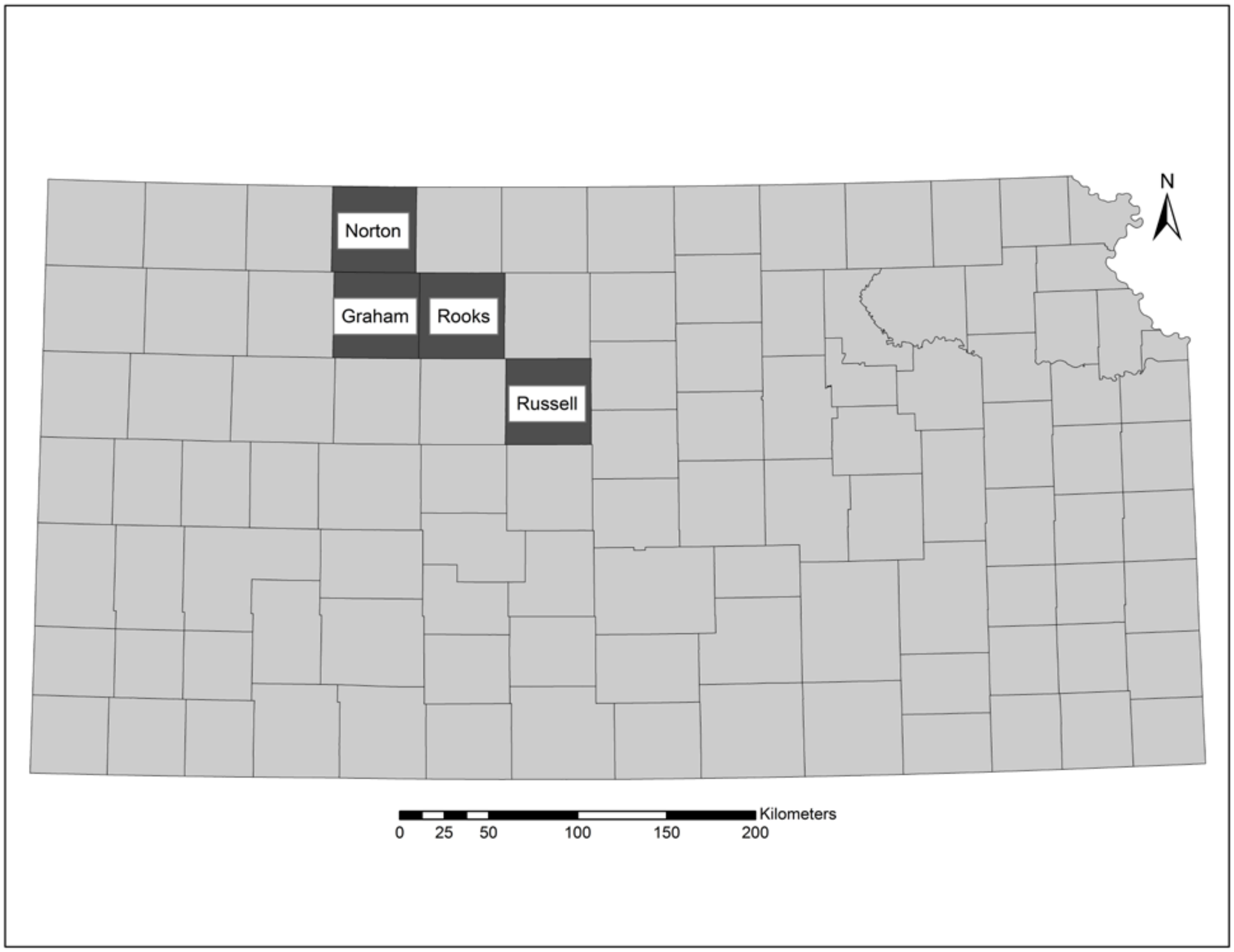


Figure 3.1. Kansas counties with the counties containing the study areas in 2017-2019, Graham, Norton, Rooks, and Russell, in dark grey.

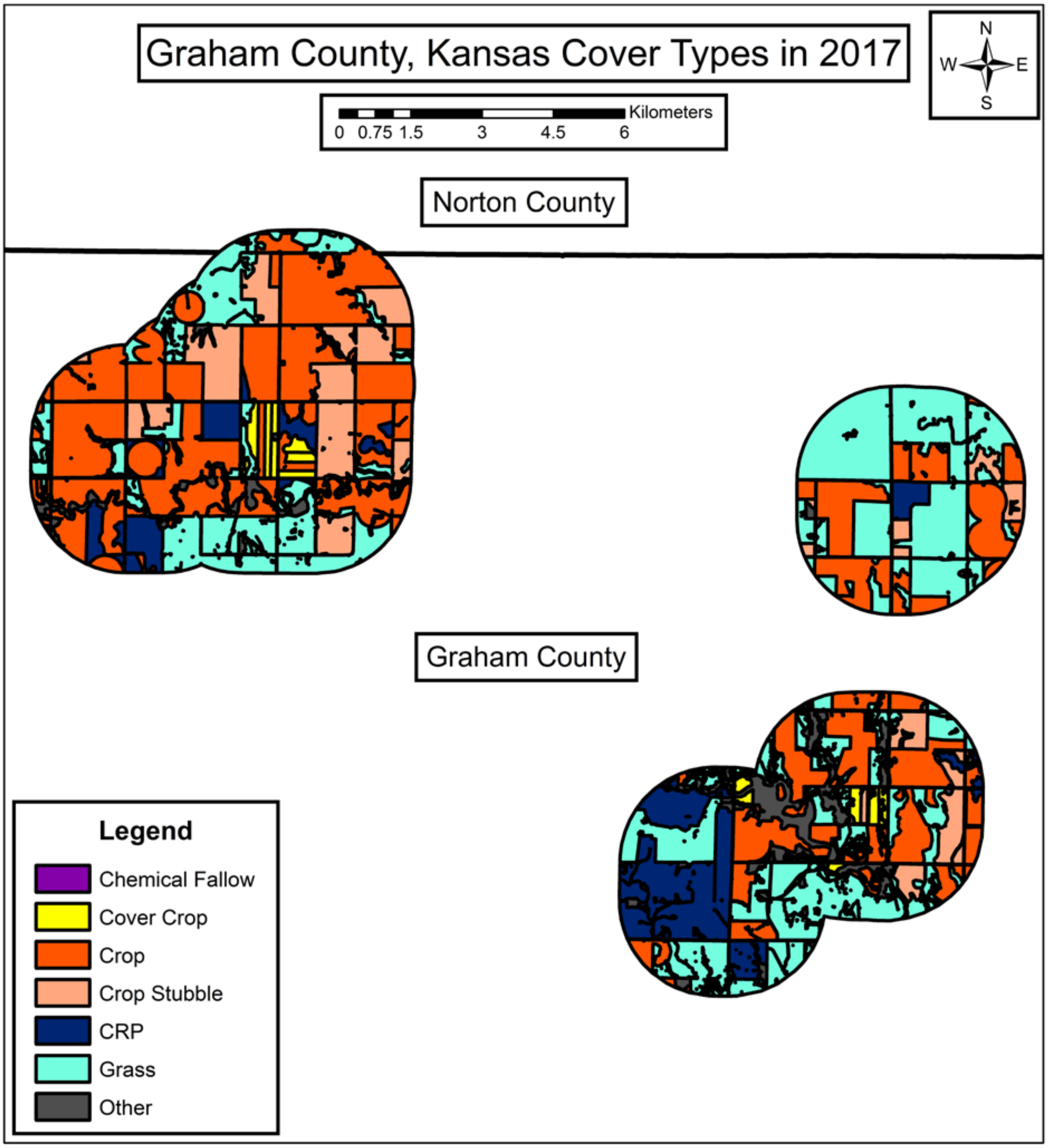
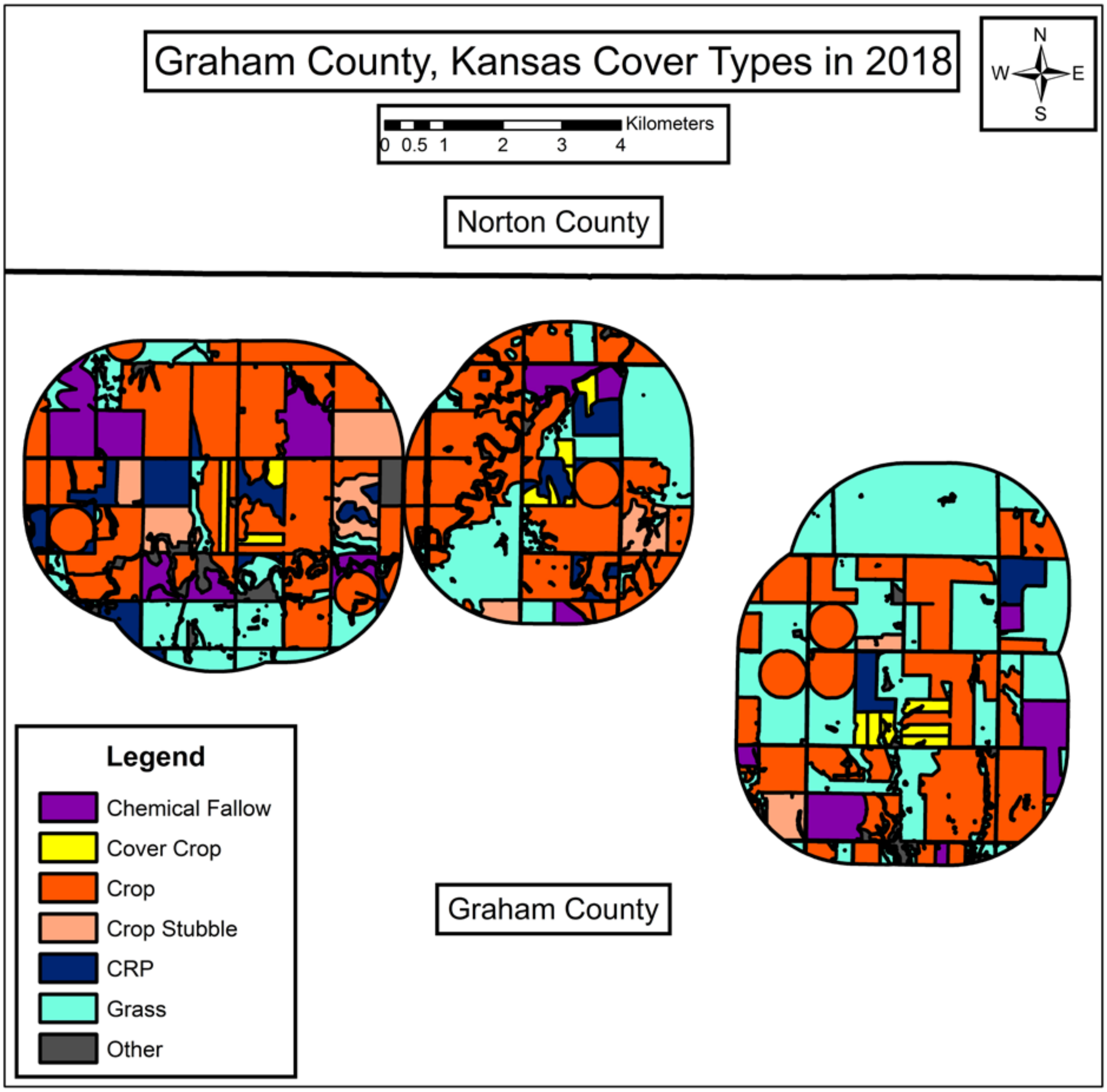


Figure 3.2. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2017 in Graham County, Kansas, USA.



Graham County, Kansas Cover Types in 2018
N
W
E
S
Kilometers
0 0.5 1 2 3 4
Norton County
Graham County
Legend
Chemical Fallow
Cover Crop
Crop
Crop Stubble
CRP
Grass
Other

Figure 3.3. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Graham County, Kansas, USA.

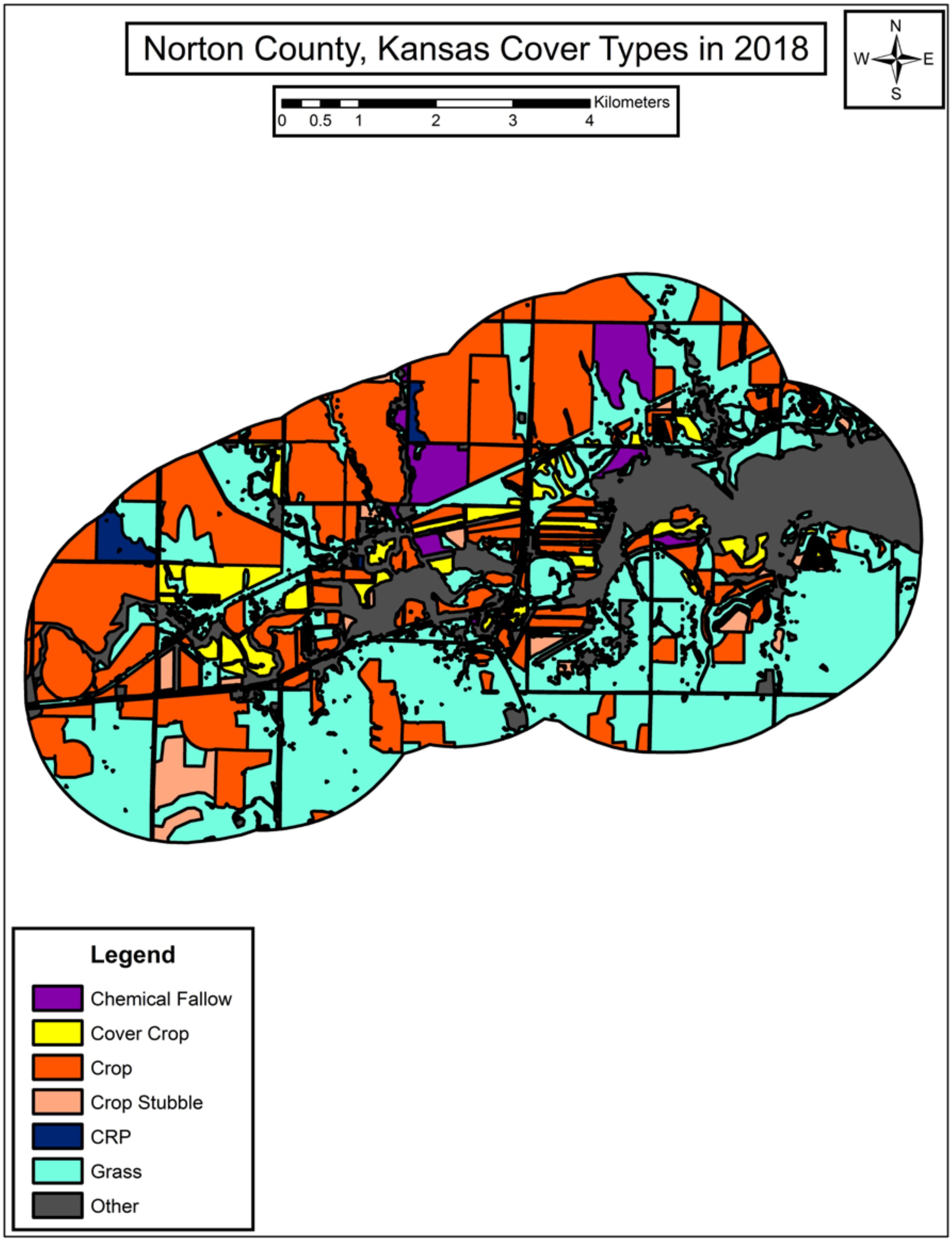


Figure 3.4. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Norton County, Kansas, USA.

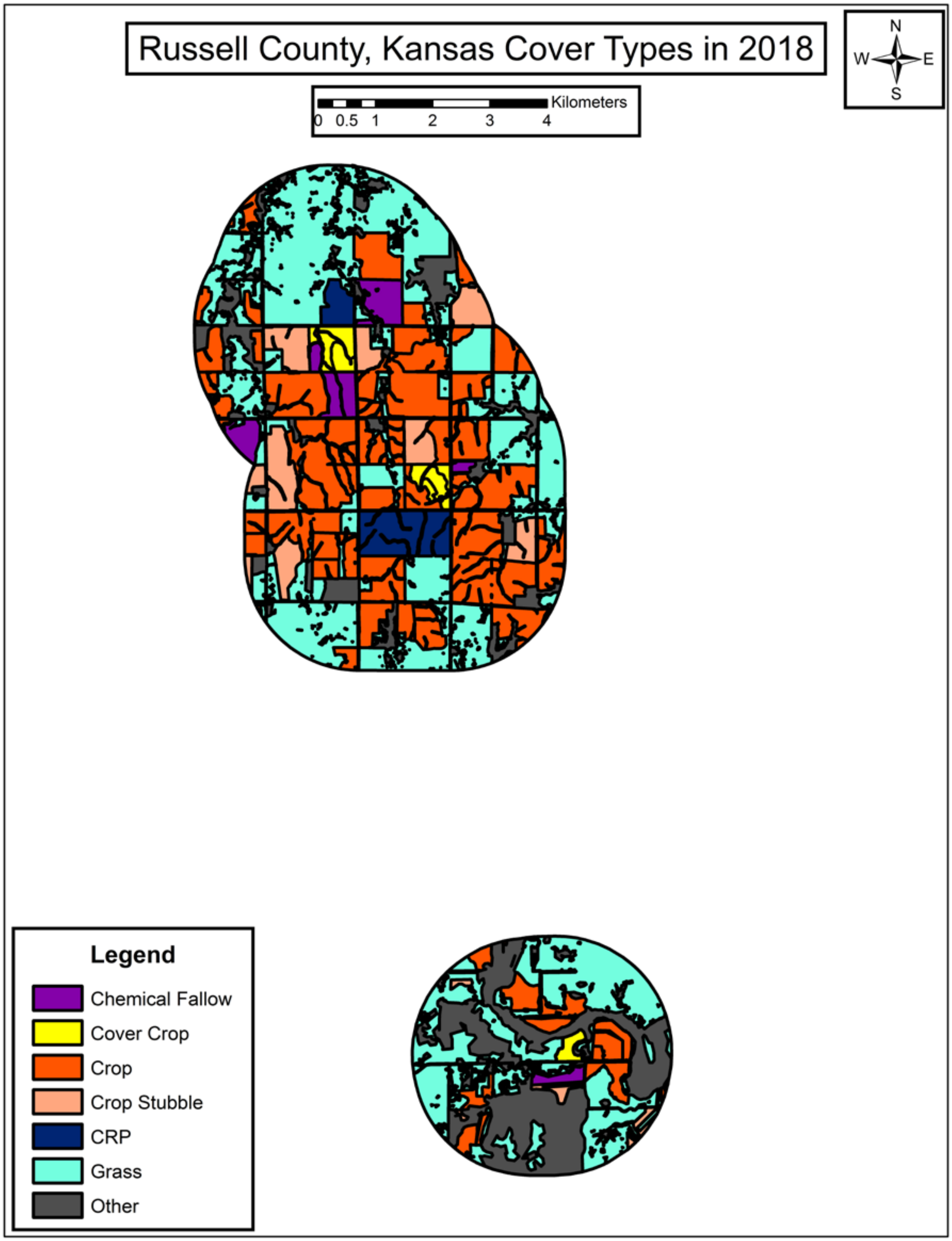


Figure 3.5. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Russell County, Kansas, USA.

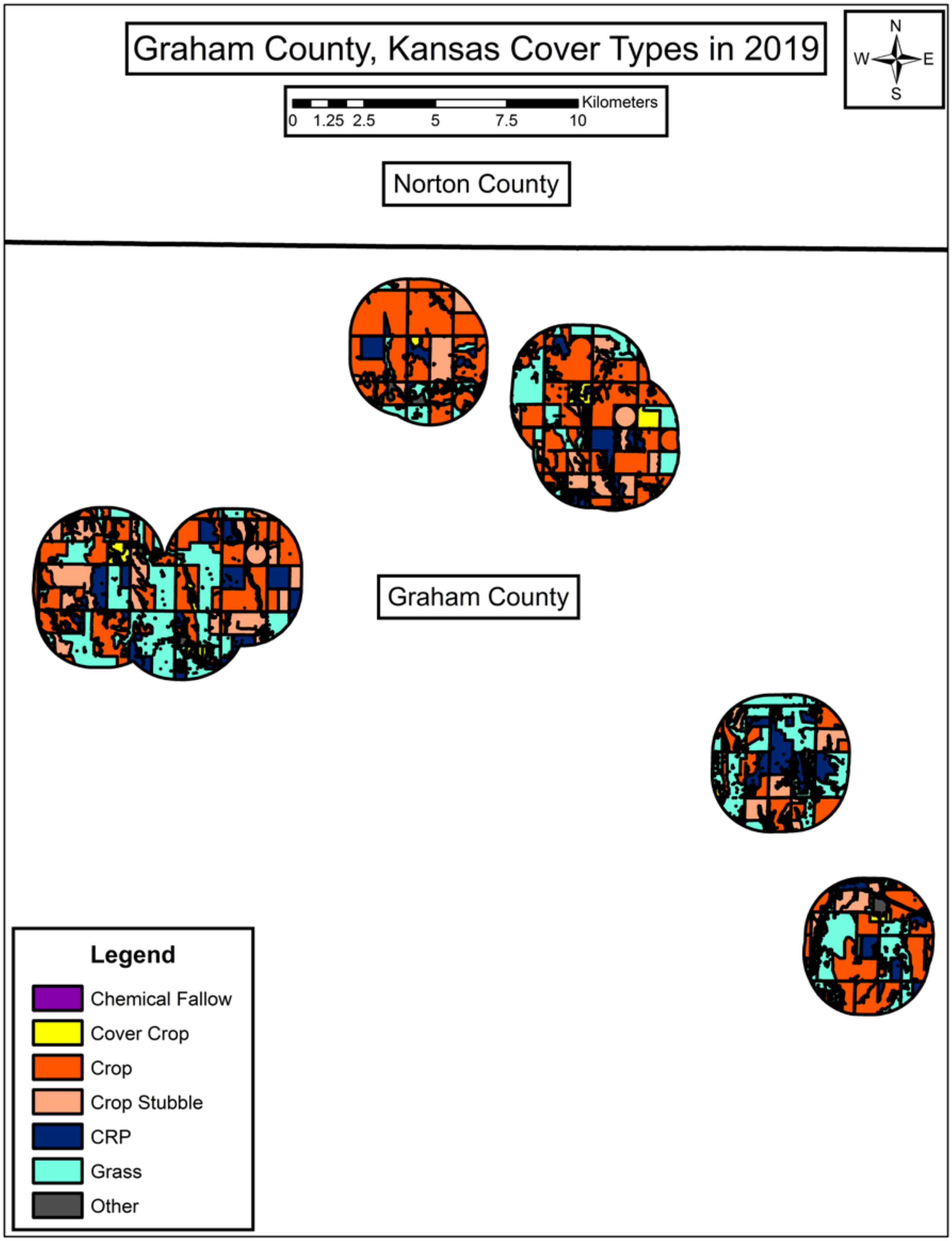


Figure 3.6. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Graham County, Kansas, USA.

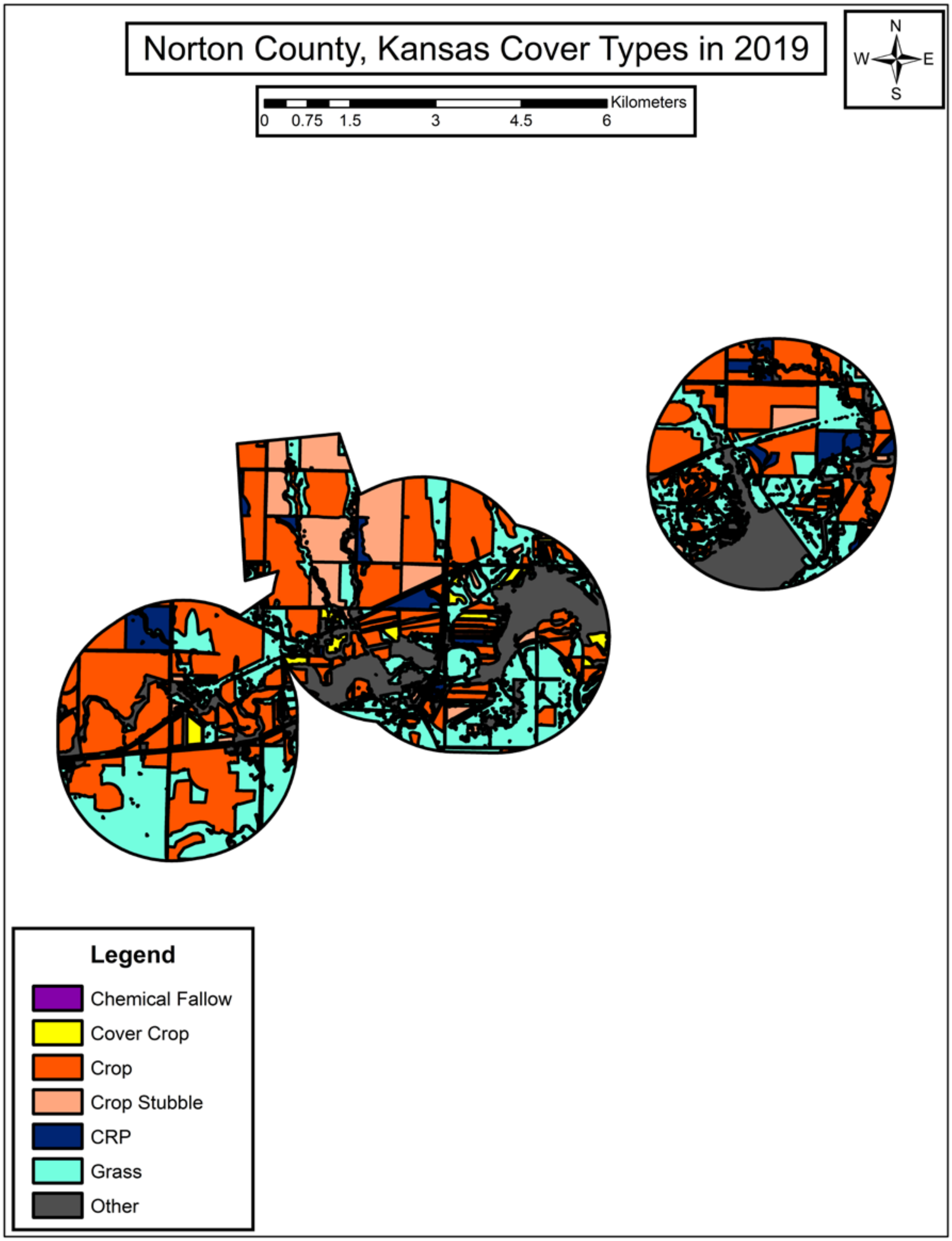


Figure 3.7. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Norton County, Kansas, USA.

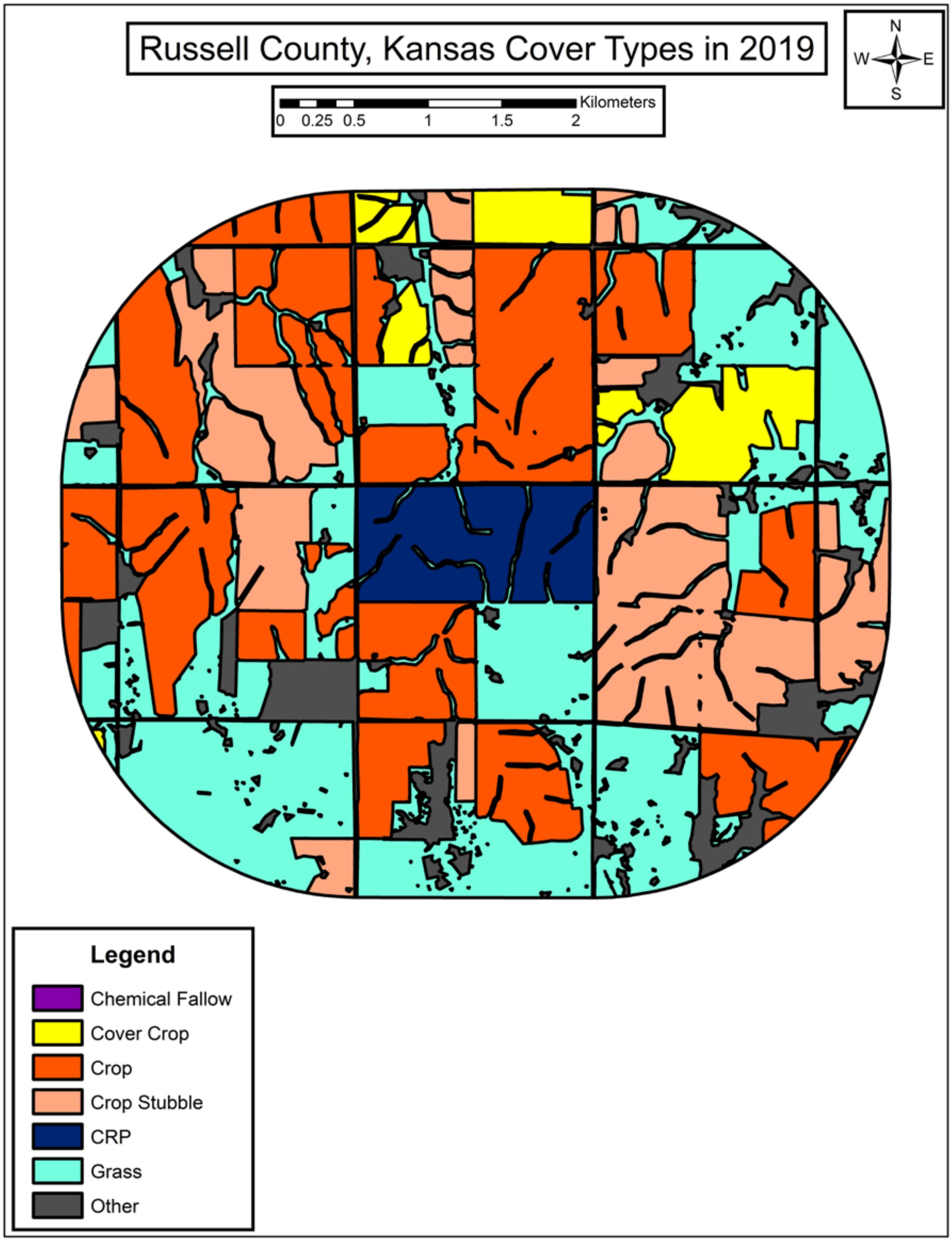


Figure 3.8. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Russell County, Kansas, USA.

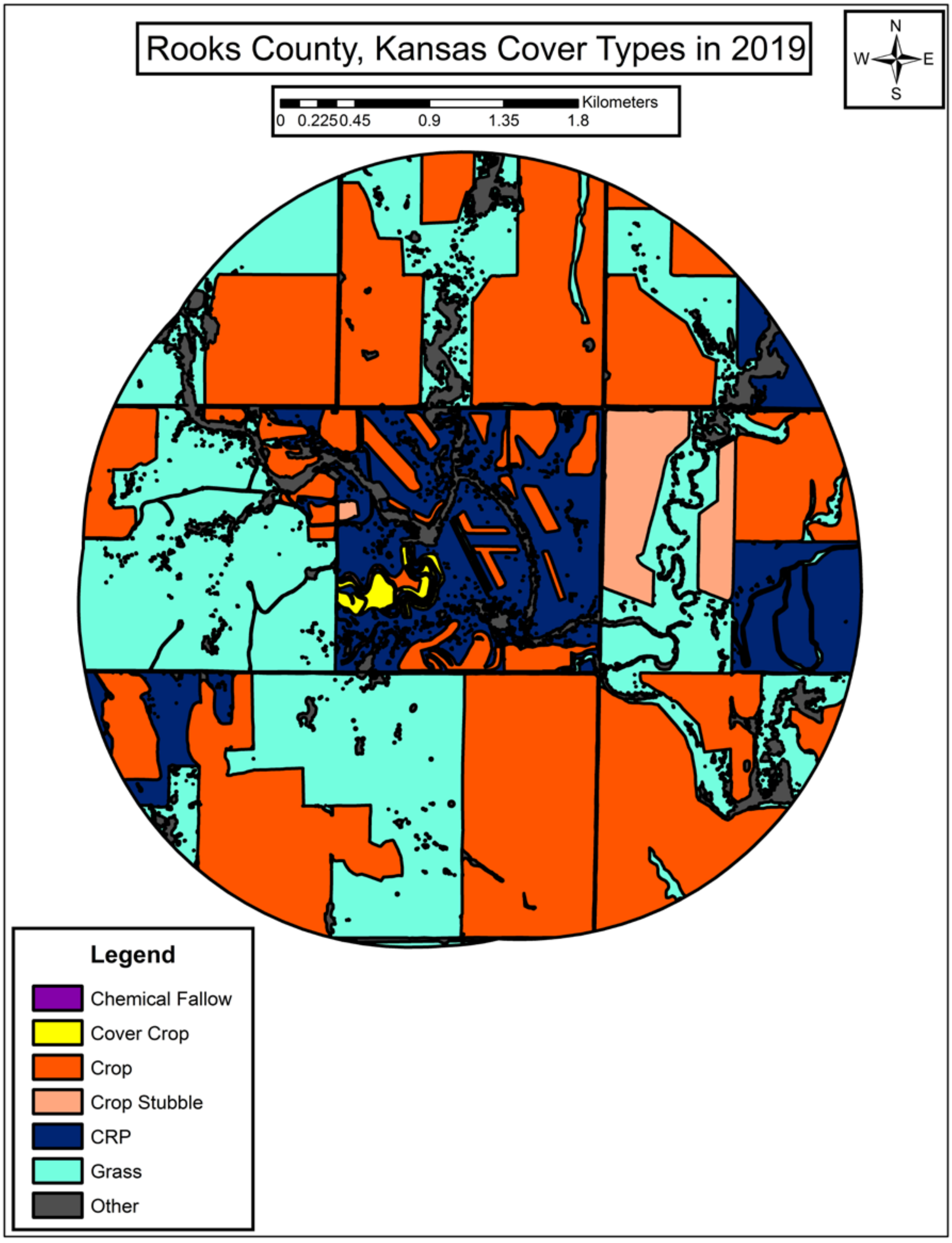


Figure 3.9. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2019 in Rooks County, Kansas, USA.

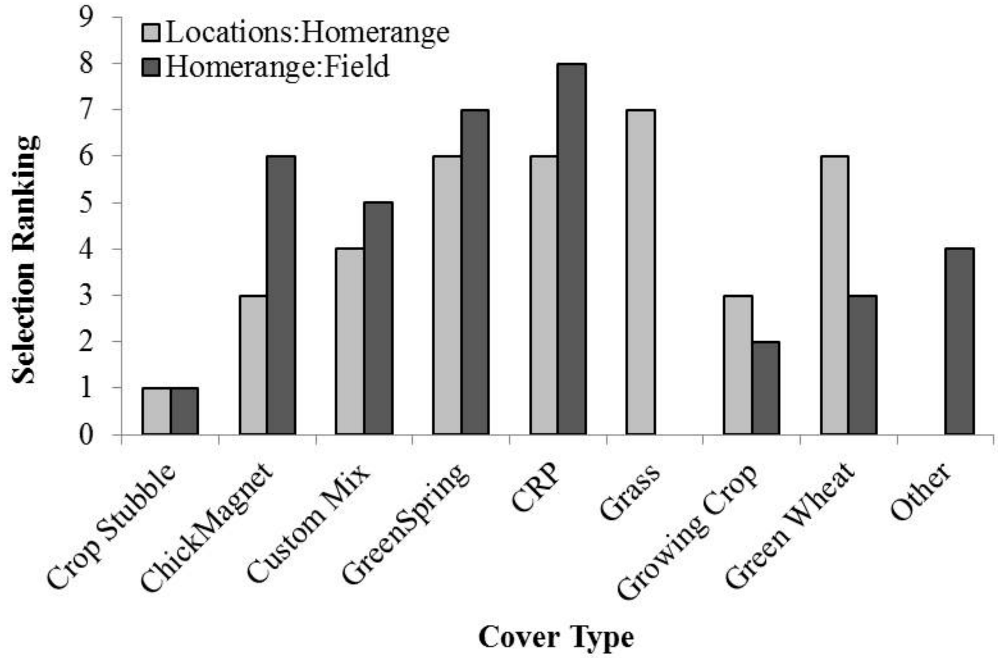


Figure 3.10. Ring-necked pheasant (*Phasianus colchicus*) hen selection rankings in western Kansas, USA, from 2017–2019, comparing locations to the 95% Kernel Density Home Range Estimate and comparing the 95% Kernel Density Home Range Estimate to 1 km around the field of capture. Higher rankings indicate pheasants select for that cover type over cover types with lower rankings within the same scale comparison.

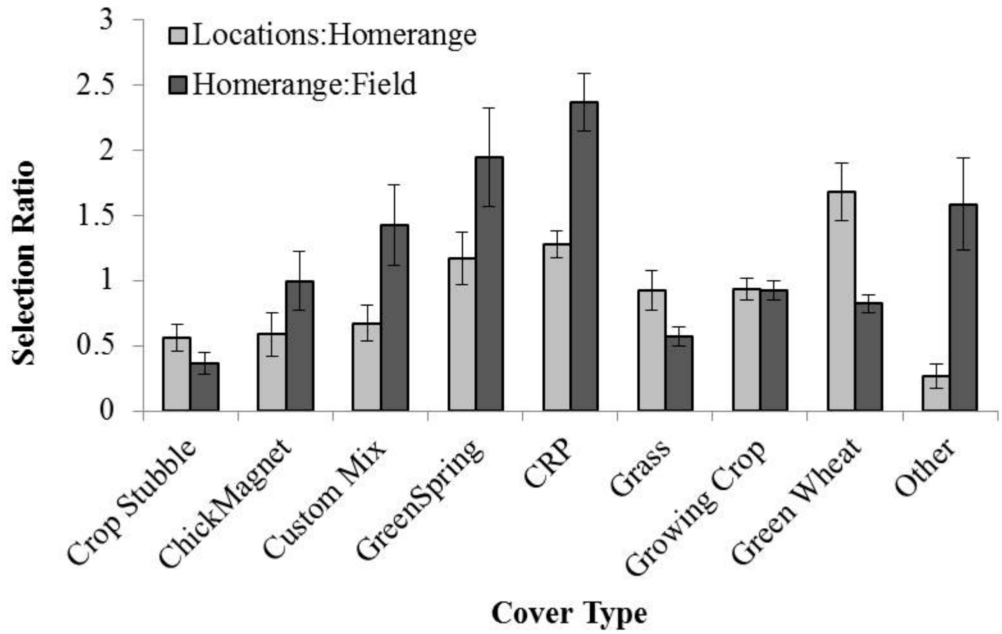


Figure 3.11. Ring-necked pheasant (*Phasianus colchicus*) hen average selection ratios and standard error bars in western Kansas, USA, from 2017–2019, comparing locations to the 95% Kernel Density Home Range Estimate and comparing the 95% Kernel Density Home Range Estimate to 1 km around the field of capture. A value of one indicates the cover type was used as available, with no selection for or against. Values <1 indicate selection against the cover type and values >1 indicate selection for the cover type.

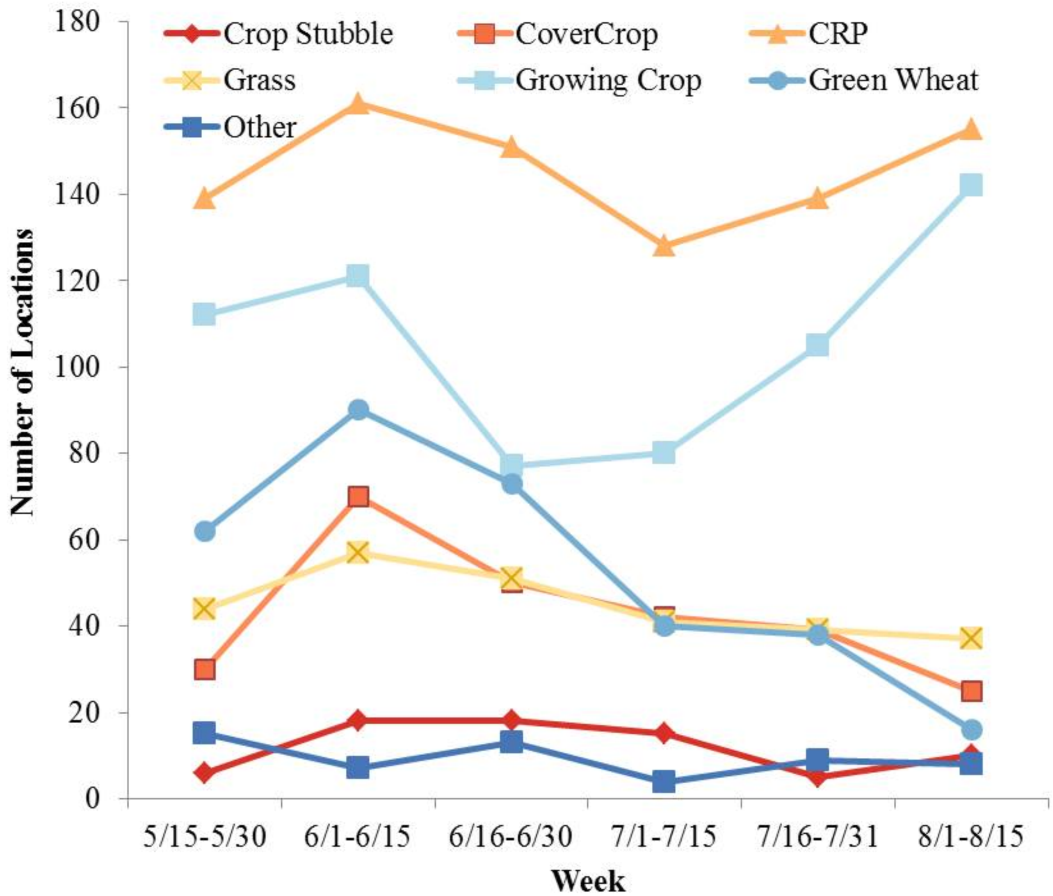


Figure 3.12. Ring-necked pheasant (*Phasianus colchicus*) hen locations (*n* = 2,482) by cover type, during cover crop growth, in western Kansas, USA, from 2017 – 2019.

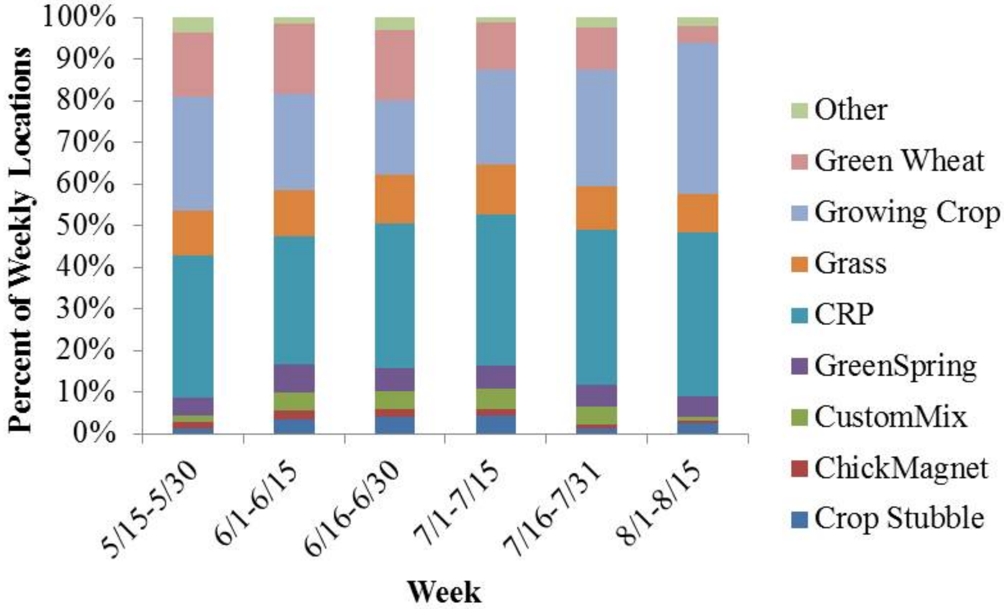


Figure 3.13. Ring-necked pheasant (*Phasianus colchicus*) hen locations (*n* = 2,482) by cover type, during cover crop growth, in western Kansas, USA, from 2017–2019.

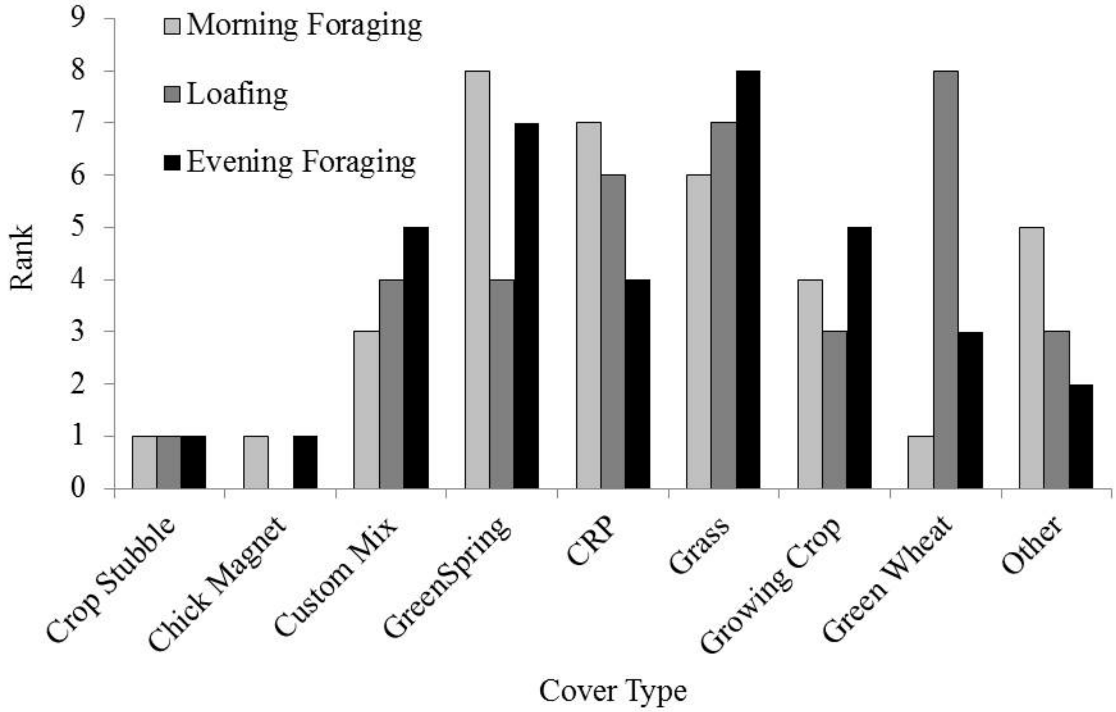


Figure 3.14. Ring-necked pheasant (*Phasianus colchicus*) hen selection rankings by diurnal time periods (morning foraging, loafing, and evening foraging) in western Kansas, USA, from 2017–2019, comparing locations in cover types to the 95% Kernel Density Home Range Estimate. Higher rankings indicate pheasants select for that cover type over cover types with lower rankings within the same scale comparison.

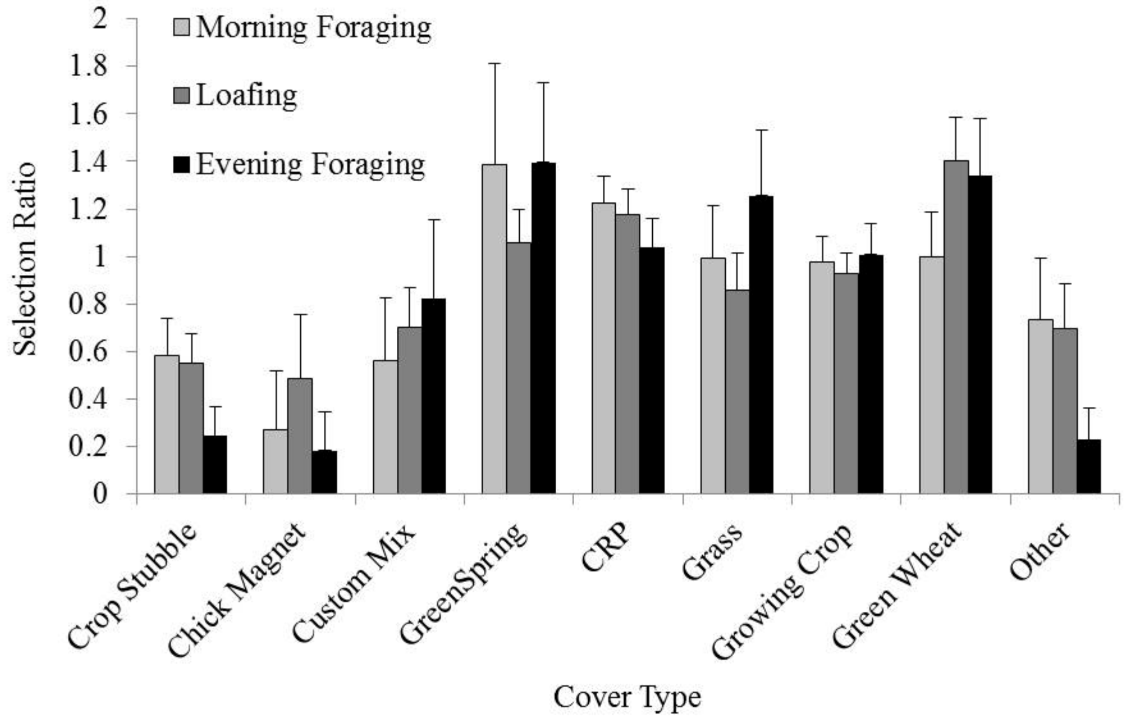


Figure 3.15. Ring-necked pheasant (*Phasianus colchicus*) hen selection rankings and standard error bars by diurnal time periods (morning foraging, loafing, and evening foraging) in western Kansas, USA, from 2017–2019, comparing locations in cover types to the 95% Kernel Density Home Range Estimate. Higher rankings indicate pheasants select for that cover type over cover types with lower rankings within the same scale comparison.

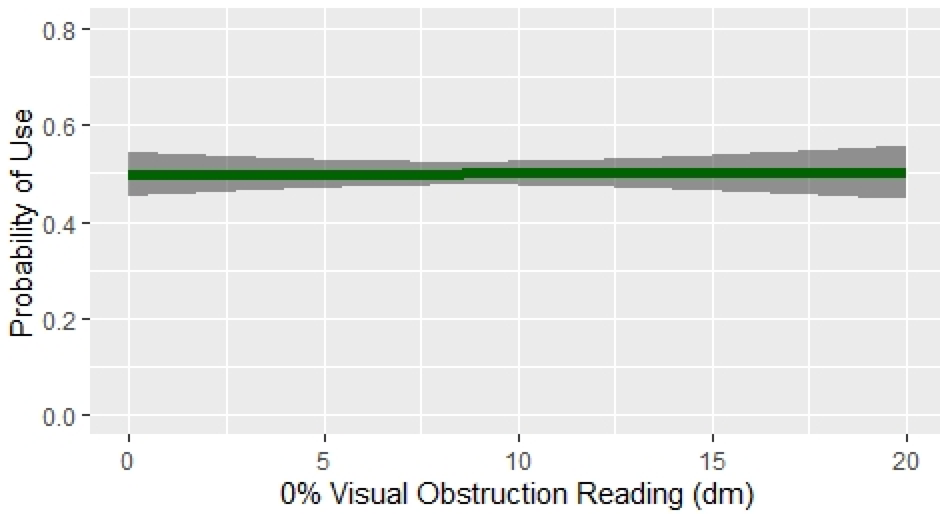


Figure 3.16. The probability of use by female ring-necked pheasants (*Phasianus colchicus*) based on the average 0% visual obstruction reading from the cardinal directions, based on the resource selection model with the most support, comparing all used to random locations, in western Kansas, USA, 2017–2019.

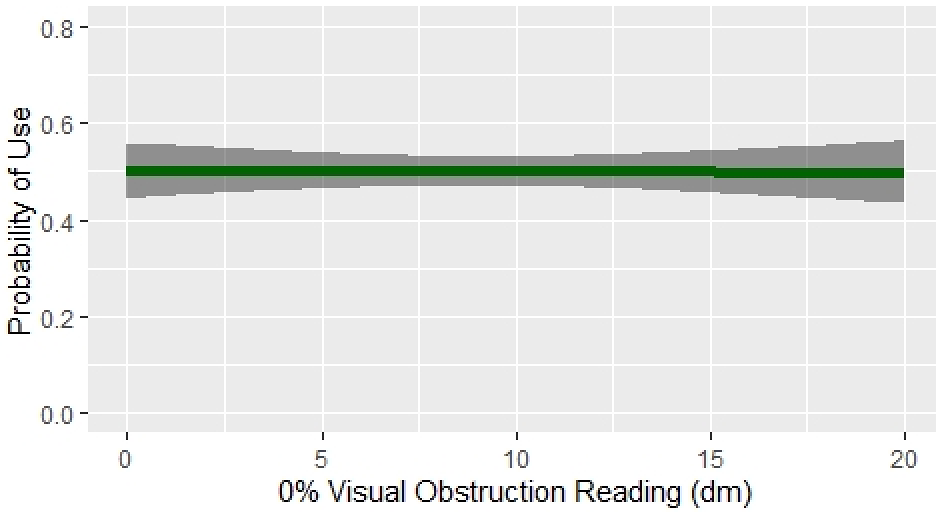


Figure 3.17. The probability of use by female ring-necked pheasants (*Phasianus colchicus*) based on the average 0% visual obstruction reading from the cardinal directions, based on the resource selection model with the most support, comparing loafing used to random locations, in western Kansas, USA, 2017–2019.

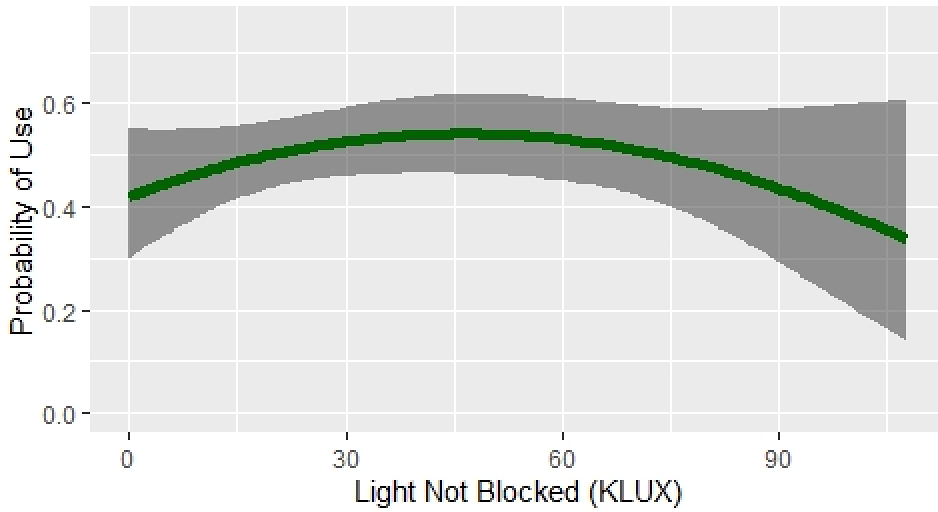


Figure 3.18. The probability of use by female ring-necked pheasants (*Phasianus colchicus*) based on the average light blocked (kLux), based on the resource selection model with the most support, comparing morning foraging used to random locations, in western Kansas, USA, 2017–2019.

Table 3.1. Summary of climate, weather and land cover of study areas in western Kansas, USA, from 2017–2019. Climate data includes long-term averages of annual precipitation totals (mm) and long-term averages of annual average temperature (° C), from 1981–2010 annual normal data at three weather stations (USW00093990-Graham and Rooks, USC00145852-Norton, USW00093997-Russell). Weather was collected at the same weather stations. Average temperature was calculated by adding the maximum temperature and minimum temperature and dividing by two. The study area land cover percentages were estimated from the project's cover type maps of the study areas from 2019. The other cover type includes trees, bodies of water, roads, and manmade objects.

	Graham	Norton	Rooks	Russell
Average Annual Temperature	11.9	11	11.9	12.6
Average Annual Total Precipitation	582.17	656.34	582.17	648.46
2017 Average Temperature	13.2	11.8	13.2	13.7
2018 Average Temperature	12.0	10.3	12.0	13.1
2019 Average Temperature	11.7	10.1	11.7	12.1
2017 Total Precipitation (mm)	590.0	325.2	590.0	439.6
2018 Total Precipitation (mm)	921.2	256.3	921.2	795.5
2019 Total Precipitation (mm)	744.7	322.8	744.7	692.8
Percent Crop	40	37	42	30
Percent Crop Stubble	13	7	3	18
Percent Cover Crop	2	1	1	5
Percent Grass	3	32	33	32
Percent CRP	12	3	15	5
Percent Other	30	20	6	10

Table 3.2. Summary of cover crop treatment field sizes and coverage within the study areas, in western Kansas, USA, 2017–2019. Average is the average size of the treatments fields (ha) and Total area is the total coverage (ha) of all the treatment fields. Cover crop mixes include GreenSpring© (73 kg/ha), Chick Magnet© (28 kg/ha) and a Custom Wildlife Mix (41 kg/ha) developed by Star Seed Company (Osbourne, Kansas, USA). Chemical fallow fields were included as a control.

	2017		2018		2019	
Treatment	Average	Total Area	Average	Total Area	Average	Total Area
Graham County						
Chemical Fallow	15.2	45.5	18.2	54.7	N/A	N/A
Chick Magnet	16.8	50.4	13.1	52.4	11.6	93.1
Custom Mix	16.9	50.5	15.3	61.2	10.6	84.5
GreenSpring	16.7	50	13.2	52.8	12.6	100.6
Norton County						
Chemical Fallow	N/A	N/A	9	35.8	7.7	15.4
Chick Magnet	N/A	N/A	4.7	37.5	5	10
Custom Mix	N/A	N/A	8.5	34.1	6.7	20.1
GreenSpring	N/A	N/A	6.8	27.2	4.9	9.8

Table 3.2 continued.

	2017		2018		2019	
Treatment	Average	Total Area	Average	Total Area	Average	Total Area
Rooks County						
Chemical Fallow	N/A	N/A	N/A	N/A	N/A	N/A
Chick Magnet	N/A	N/A	N/A	N/A	6	18.1
Custom Mix	N/A	N/A	N/A	N/A	6.7	20
GreenSpring	N/A	N/A	N/A	N/A	5.5	16.5
Russell County						
Chemical Fallow	N/A	N/A	26.9	53.9	8	8
Chick Magnet	N/A	N/A	14.9	29.9	10.5	31.4
Custom Mix	N/A	N/A	13.8	27.7	9.1	36.5
GreenSpring	N/A	N/A	14.8	29.6	8.7	34.9
All Counties						
Chemical Fallow	15.2	45.5	54.1	144.4	7.85	23.4
Chick Magnet	16.8	50.4	32.7	119.8	33.1	152.6
Custom Mix	16.9	50.5	37.6	123	33.1	161.1
GreenSpring	16.7	50	34.8	109.6	31.7	161.8

Table 3.3. Ring-necked pheasant (*Phasianus colchicus*) hen movement measurements during the breeding season (April 1 – August 18) in western Kansas, USA, from 2017–2019, including exploratory movements (the maximum distance from the mean center of the home range to an individual location) and farthest distance (the farthest distance between two individual locations).

Statistic	Exploratory (m)	Farthest Distance (m)
Minimum	405.8	653.7
Median	755.4	1246.6
Mean	863.8	1331.9
Maximum	2376.4	3415.4
Standard Deviation	386.2	536.4

Table 3.4. Ring-necked pheasant (*Phasianus colchicus*) hen resource selection function results comparing vegetation surveys at used and random locations (n = 1,633) within the same cover type patch, in western Kansas, USA, 2017–2019, showing only models with support (<2 ΔAIC_c).

Model	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	K
0% VOR	2271.98	0.00	0.97	2
Average Percent Bare Ground	2282.71	10.74	0.00	2
Average Percent Ground	2282.82	10.84	0.00	2
Average Percent Vegetation	2282.86	10.88	0.00	2
Average Overhead Cover	2283.07	11.10	0.00	2
Quadratic Average Overhead Cover	2284.18	12.21	0.00	3
Average Percent Grass	2284.32	12.34	0.00	2
Quadratic Average Percent Vegetation	2284.57	12.60	0.00	3
Quadratic Average Percent Ground	2284.64	12.66	0.00	3
Quadratic Average Percent Bare Ground	2284.70	12.72	0.00	3

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, K- number of parameters

Table 3.5. Ring-necked pheasant (*Phasianus colchicus*) hen resource selection function results comparing vegetation surveys at used and random loafing locations (n = 1,053) within the same cover type patch, in western Kansas, USA, 2017 – 2019, showing only models with support (<2 ΔAIC_c). Loafing locations occurred between the two foraging time periods, starting two hours after sunrise and ending two hours before sunset.

	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	K
0% VOR	1455.46	0	0.51	2
Quadratic 0% VOR	1457.44	1.99	0.19	3
Average Percent Bare Ground	1459.32	3.86	0.07	2
Average Percent Ground	1459.55	4.1	0.07	2
Average Percent Vegetation	1459.62	4.16	0.06	2
Average Percent Grass	1460.58	5.13	0.04	2
Quadratic Average Percent Vegetation	1460.68	5.22	0.04	3
Quadratic Percent Bare Ground	1461.27	5.81	0.03	3

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, *K*- number of parameters

Table 3.6. Ring-necked pheasant (*Phasianus colchicus*) hen resource selection function results comparing vegetation surveys at used and random morning foraging locations (*n* = 335) within the same cover type patch, in western Kansas, USA, 2017 – 2019, showing only models with support (<2 ΔAIC_c). Foraging locations occur from sunrise to two hours after sunrise and two hours before sunset to sunset.

Model	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	*K*
Quadratic Overhead Cover	465.32	0.00	0.26	3
0% VOR	465.42	0.10	0.25	2
Overhead Cover	465.63	0.32	0.23	2
25% VOR	466.71	1.39	0.13	2
50% VOR	466.80	1.48	0.13	2

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, K- number of parameters

Table 3.7. Ring-necked pheasant (*Phasianus colchicus*) hen resource selection function results comparing vegetation surveys at used and random evening foraging locations (n = 245) within the same cover type patch, in western Kansas, USA, 2017 – 2019, showing only models with support (<2 ΔAIC_c). Foraging locations occur from sunrise to two hours after sunrise and two hours before sunset to sunset.

Model	AIC_c[a]	ΔAIC_c	$AIC_c\ w_i$	K
0% VOR	339.34	0.00	0.48	2
Average Percent Forb	342.91	3.57	0.08	2
Average Percent Litter	343.15	3.81	0.07	2
Average Percent Bare Ground	343.41	4.07	0.06	2
Average Percent Vegetation	343.44	4.10	0.06	2
Average Overhead Cover	343.54	4.20	0.06	2
Average Percent Grass	343.6	4.25	0.06	2
Average Percent Ground	343.63	4.29	0.06	2
Quadratic Average Percent Ground	344.1	4.76	0.04	3
Quadratic Average Percent Forb	344.62	5.28	0.03	3

[a]AIC*c*- Akaike's Information Criterion for small sample sizes, ΔAIC*c* - differences in $AIC_c\ w_i$ - Akaike weights, K- number of parameters

Chapter 4 - Invertebrate and vegetation characteristics of spring cover crops

Introduction

Use of spring cover crops to increase nesting and brood-rearing habitat for grassland birds in agricultural landscapes is a rapidly emerging management practice. Continued agricultural intensification negatively affects bird species commonly found on croplands and other converted grasslands (Stanton et al. 2018). Increased use of pesticides in crop fields reduce local forage resources for wildlife, crop fields fragment and alter the landscape affecting space use and movements by wildlife, and crop fields can serve as ecological traps negatively affecting population demography of wildlife (Stanton et al. 2018). Spring cover crops may help counter these negative effects while providing agricultural benefits by converting fallow fields to green fields that can benefit ground-nesting birds. Altering agriculturally dominated regions, like western Kansas, may impact long-term population trends for grassland birds (Stanton et al. 2018).

A typical crop rotation practice in western Kansas is to leave fields fallow after corn (Zea mays) or grain sorghum (Sorghum bicolor) harvest in the fall until winter wheat (Triticum sp.) is planted the following fall (~12-14 months; Roozeboom et al. 2009). Herbicides are used to maintain the fallow state. Nesting and brood-rearing efforts for ring-necked pheasants (*Phasianus colchicus*; hereafter pheasant) and other birds occur within the period when field would be fallow. The presence of fallow fields isolate potential nesting patches and provide minimal cover and forage for wildlife. Use of spring cover crops benefits producers with ecological goods and services including increased organic matter, nitrogen fixing, soil nutrient movement and reduced weeds, and reduced soil compaction and erosion (Villami et al. 2006, Wayman et al. 2014, Ladoni et al. 2016).

Wildlife, including pheasants, may benefit from the additional cover and food resources provided by spring cover crops during breeding (Jeliazkov et al. 2016, KDWPT 2016, Wilcoxen et al. 2018). Many spring cover crop seed mixes contain small grains, which pheasants use as nesting and brood-rearing sites (Warner 1979, Flake et al. 2012, Wilcoxen et al. 2018; Chapter II). Other mixes contain a wide variety of forbs, which attract invertebrates, providing additional food resources for pheasant broods. Producers can select mixes to potentially provide nesting habitat, brooding habitat, or both (KDWPT 2016, Wilcoxen et al. 2018). Companies have commonly developed commercial mixes, but will often create custom mixes of varying complexity by request. Simple mixes can contain two plant species, whereas more complex blends can contain ≥10 species. Although use of cover crops is considered beneficial for most wildlife species by decreasing homogeneity of agricultural landscapes and providing accessible food and cover resources (Jeliazkov et al. 2016), wildlife responses to different mixes are relatively undocumented. Bird diversity increases in cover crop fields compared to fallow fields, but mechanisms driving this difference are unknown, limiting the potential to maximize wildlife benefits (Wilcoxen et al. 2018).

Cover crops may mitigate the negative effects of pesticides and habitat fragmentation. Using common wildlife habitat measurements for vegetation and insects, I compared various spring cover crop seed mixes to chemical fallow (the alternative practice, experimental control) but also to extant wheat fields (the dominant crop) and U.S. Department of Agriculture Conservation Reserve Program (CRP) land (experimental positive control as baseline wildlife habitat). Cover crops providing vegetation characteristics and insect forage similar to CRP land could provide additional resources to local wildlife and help maintain local pheasant populations. I tested three seed mixes: a wildlife focused warm-seasoned forb mix, a traditional agricultural blend, and a customized mix for diversity. My research objectives were to (1) assess if cover crops provide more cover and invertebrates than chemical fallow (my negative control), (2) compare vegetation and invertebrates among cover crop seed mixes, (3) determine if cover crops provide similar resources as CRP (my positive control), and (4) assess the importance of seed mix relative to providing additional vegetation and invertebrates on the landscape for local wildlife. I predicted the wildlife blend would provide the largest invertebrate count and biomass of all the cover crop seed mixes but CRP would provide the most invertebrate diversity. I also predicted CRP would provide the most visual obstruction, litter, overhead cover, and grass cover of all cover types. The wildlife seed mix, by comparison, would provide the most forb cover

Study Area

I researched pheasants in two ecoregions of Kansas during the 2017–2019 breeding seasons: High Plains (Graham and Norton counties) and Smoky Hills (Rooks and Russell counties; Fig. 4.2). Counties were dominated by cropland and interspersed with Conservation Reserve Program (CRP) land and native grassland (National Soil Cooperative 1977; 1982a,b; 1986). Wheat (Triticum sp.) is the primary cash crop in both ecoregions, with >50% of the cropland planted to wheat. The remaining cropland consisting of corn (Zea mays), grain sorghum (Sorghum bicolor), soybeans (Glycine max), and fallow areas (National Soil Cooperative 1977; 1982a,b; 1986). A typical crop rotation consists of corn or grain sorghum and a 12-14-month fallow period followed by winter wheat (Roozeboom et al. 2009, KDWPT 2016b).

The High Plains consists of short-grass prairie with mixed- and western tall-grass prairies (Lauver et al. 1999). The short-grass prairie is dominated by blue grama (Bouteloua gracilis) and buffalograss (Bouteloua dactyloides) with scattered purple threeawn (Aristida purpurea), broom snakeweed (Gutierrezia sarothrae), slimflower scurfpea (Psoralidium tenuiflorum), and upright prairie coneflower (Ratibida columnifera; Lauver et al. 1999). The western tall-grass prairie, in the High Plains, is predominantly comprised of big bluestem (Andropogon gerardii) and indian grass (Sorghastrum nutans) with intermixed Illinois bundleflower (Desmanthus illinoensis), American licorice (Glycyrrhiza lepidota), switchgrass (Panicum virgatum), western wheatgrass (Pascophyrum smithii), common threesquare (Schoenoplectus pungens), and sand dropseed (Sporobolus cryptandrus; Lauver et al. 1999).

In the Smoky Hills, the Dakota Hills tall-grass prairie is comprised of big bluestem, switchgrass, little bluestem (Schizachyrium scoparium), with sideoats grama (Bouteloua curtipendula), Fremont’s clematis (Clematis fremontii), indian grass, prairie spiderwort (Tradescantia occidentalis), and Tharp’s spiderwort (Tradescantia tharpii; Lauver et al. 1999). The mixed-grass prairie in both regions is dominated by little bluestem, sideoats grama, and blue grama (Bouteloua gracilis) with ragweed (Ambrosia psilostachya), big bluestem, groundplum milkvetch (Astragalus crassicarpus var. crassicarpus), hairy grama (Bouteloua hirsuta), buffalograss, yellow sundrops (Calylophus serrulatus), nineanther prairie clover (Dalea enneandra), blazing star (Liatris punctate), and Indian grass (Lauver et al. 1999).

Study areas were cover crop treatment fields, negative control chemical fallow fields, positive control CRP and active wheat fields. In 2017, the study area consisted of 9,945 ha in Graham County. In 2018, I expanded into Russell and Norton counties (19,939 ha) and decreased the area I cover in Graham County (424.8 ha; Table 4.1). The Norton County study areas were located on the Norton State Wildlife Management Area, all other study areas were on private land. Annual long-term average precipitation and temperature were similar among counties (Table 4.2).

Methods

I collaborated with landowners in western Kansas to plant spring cover crop treatment fields in landscapes supporting pheasants during 2017-2018. Fields were in rotation for fall planting of winter wheat after a grain crop (corn or milo). Each study field was ~65 ha (quarter section; 120 acres), located adjacent to CRP land and divided equally into four treatment plots (~17 ha) - three spring cover crop mixes and a chemical fallow control. Treatments were randomly assigned to each plot within the field. Cover crops were planted in mid-March to mid-April, with chemical termination of cover crops in late June or July to be in compliance with crop insurance requirements.

Seed Mixes

Three cover crop seed mixes were tested including GreenSpring© (73 kg/ha), Chick Magnet© (28 kg/ha) and a Custom Wildlife Mix (41 kg/ha). GreenSpring© was a common mix developed by Star Seed Company (Osbourne, KS, USA) for its agricultural benefits and potential to hay the crop for use as cattle feed. The mix contained cool-season peas (Pisum sativum) and oats (Avena sativa). Chick Magnet© was designed by Star Seed Company for precocial gamebird chicks. The mix contained warm-season, broad-leafed forbs that offer extensive overhead concealment with sparse stems for easy movement by chicks. Species included in the mix were: cowpeas (Vigna unguiculata), cool-season peas, yellow sweet clover (Melilotus officinalis), hybrid brassica (Brassica spp.), sunflower (Helianthus spp.), and buckwheat (Fagopyrum esculentum). The final mix was a custom mix designed by Star Seed Company and

Kansas Department of Wildlife, Parks, and Tourism to be adaptive to different climatic conditions and provide a variety of resources for wildlife. Species included were chickling vetch (Vicia villosa), radish (Raphanus raphanistrum), oats, cool-season peas, rapeseed (Brassica napus), sunflowers (Helianthus spp.), turnips (Brassica rapa), and yellow sweet clover. I also had a chemical fallow control treatment as a control where nothing was planted and the landowner used herbicide to prevent weed encroachment into the field. This treatment represented the standard agriculture practice in the absence of planting spring cover crops.

Surveys

I conducted weekly vegetation surveys in cover crop, fallow control, CRP, and active wheat fields. I randomly generated five point locations weekly in ArcMap 10.3 within each field. I measured vegetation composition using a Daubenmire frame and visual obstruction with a Robel pole. I measured the percent cover of bare ground, litter, forbs, warm-season grasses, cool-season grasses, woody species greater and less than 1.5 m, crop, and standing crop stubble within a 60-cm Daubenmire frame at each point and 4 m to the north, south, east, and west of each point (Daubenmire 1959). Litter (unrooted, dead vegetation) depth was measured in the northeast corner of each frame using a ruler (cm). I gently inserted the ruler into the litter, careful to push the litter aside instead of downwards. Visual obstruction surveys measured the highest dm with 100%, 75%, 50%, 25%, and 0% visual obstruction of the Robel pole at the cardinal directions from 4 m away at 1 m above ground (Robel et al. 1970). I estimated an index to overhead cover by subtracting the light intensity (kLux) at ground level from the light intensity at 1 m above ground to determine the light blocked by vegetation (Extech® EasyView Light Meter, Extech Instruments, Nashua, NH, USA).

I conducted biweekly invertebrate sweep surveys within the same fields as vegetation surveys. I randomly generated locations in ArcMap 10.3 within the field boundaries to locate survey starting points. I collected two sets of sweep surveys per field. I took 100 sweeps heading north, sweeping with the rows, and depositing collected invertebrates in a large plastic bag. I collected three transects per survey, taking five paces to the east and turning around in between the first two transects and turning west in between the second and third transects (Sullins et al. 2018).

Statistical Analyses

I used multivariate analysis of covariance (MANCOVA) for vegetation measurements and a multivariate analysis of variance (MANOVA) for invertebrate measurements to compare cover types. I included a week effect as a continuous independent variable for vegetation to account for vegetation growth across the time period but because invertebrate responses fluctuated, I did not include a week variable for the invertebrate analysis. If the MANCOVA indicated significant differences, I used analyses of variance (ANOVA) to test for differences among cover types for each dependent variable. Cover types were compared using a Least Significant Difference (LSD) test following a significant F test ($P \leq 0.05$). Vegetation characteristics were a subset of measured vegetation characteristics and included 75% Visual Obstruction Reading (VOR), litter depth, percent grass, percent forb, percent bare ground, and overhead cover (Klux). Vegetation and invertebrate samples were analyzed separately. Invertebrate and invertebrate orders that comprised <10% of the total biomass or count data were pooled for analyses, including Ephemenopteran, Hymenopteran, Mantodean, Neuropteran, Odonata, Phasmatodean, Thysanopteran, and Ixodidan. I analyzed Araneae, Coleopteran, Dipteran, Hemipteran, Lepidopteran, and Orthopteran individually for biomass and Araneae, Coleopteran, Dipteran, Hemipteran, and Psocopteran individually for counts. I defined "Richness" as the number of orders present in the sample. I set $\alpha = 0.05$ for all statistical tests.

Results

In 2017, my study was limited to Graham County (Table 4.2). There were three sets of spring cover crop treatment fields and negative controls (Table 4.2). In 2018, I had eight treatment sets across 3 counties. The Norton County fields were small, so I pooled multiple fields for each of the two treatment sets in the county. Fields varied in size and shape (Table 4.2; Figs. 4.2 – 4.5). All invertebrate samples analyzed were from June 2017, Graham County, while vegetation surveys were from May – August in both 2017 and 2018, all counties. Response to COVID-19 prematurely ceased the sample processing.

Invertebrate (Wilks $\lambda = 0.07$, $F_{5,376} = 18.66$, $P < 0.0001$, $n = 382$) and vegetation measurements (Wilks $\lambda = 0.15$, $F_{5,3247} = 256.94$, $P < 0.0001$, $n = 3{,}316$) varied by cover type. Invertebrate richness ($F_{5,376} = 115.0$, $P < 0.0001$), invertebrate total count ($F_{5,376} = 20.7$, $P < 0.0001$), Araneae count ($F_{5,376} = 29.8$, $P < 0.0001$), Coleoptera count ($F_{5,376} = 16.1$, $P < 0.0001$), Diptera count ($F_{5,376} = 20.0$, $P < 0.0001$), Hemiptera count ($F_{5,376} = 16.1$, $P < 0.0001$), Psocoptera count ($F_{5,376} = 21.8$, $P < 0.0001$), total mass ($F_{5,376} = 25.1$, $P < 0.0001$), Araneae mass ($F_{5,376} = 33.6$, $P < 0.0001$), Coleoptera mass ($F_{5,376} = 12.8$, $P < 0.0001$), Diptera mass ($F_{5,376} = 11.1$, $P < 0.0001$), Hemiptera mass ($F_{5,376} = 20.3$, $P < 0.0001$), Lepidoptera mass ($F_{5,376} = 14.5$, $P < 0.0001$), and Orthoptera mass ($F_{5,376} = 10.5$, $P < 0.0001$) varied by cover type. For measured vegetation variables, 75% visual obstruction ($F_{5,3247} = 77.4$, $P < 0.0001$), average percent bare ground ($F_{5,3247} = 197.0$, $P < 0.0001$), average percent grass ($F_{5,3247} = 1782.6$, $P < 0.0001$), average percent forb ($F_{5,3247} = 145.9$, $P < 0.0001$), overhead cover ($F_{5,3247} = 107.67$, $P < 0.0001$), and litter depth ($F_{5,3247} = 95.3$, $P < 0.0001$) varied by cover type. Chemical fallow plots differed from cover crop plots for the number of invertebrate orders present, invertebrate count, invertebrate biomass, vegetation structure, and vegetation composition. Chemical fallow had less invertebrate diversity (Fig. 4.6), fewer invertebrates (Figs. 4.7, 4.8), and less invertebrate biomass (Figs. 4.9, 4.10). Chick Magnet had less grass than the other treatment fields (Fig. 4.11). Chemical fallow had less forb cover, less bare ground, deeper litter, shorter visual obstruction and less light block than the other cover crop treatments (Figs. 4.12 – 4.16).

There was significant variation among cover types for invertebrate measurements. The most invertebrate orders were found in CRP whereas wheat fields and cover crop treatments were comparable (Fig. 4.6). Chick Magnet supported the greatest invertebrate count, but CRP and Chick Magnet cover types were the same to the thousandth for total dry biomass (Figs. 4.7, 4.9). Among the cover crop treatments, Custom Mix had the smallest invertebrate counts, while GreenSpring had the smallest biomass (Figs. 4.7, 4.9). Individual invertebrate order counts and biomass varied by cover type (Figs. 4.8, 4.10). Hempiterans had the greatest counts for the individual orders (Fig. 4.8). Average Hempiteran counts were greatest in Chick Magnet ($\bar{x}$ = 114 ± 17 [SE]); CRP had the second lowest count ($\bar{x}$ = 32 ± 3), though still much greater than chemical fallow fields (0; Fig. 4.8). Hemipteran biomass followed the same pattern (Fig. 4.10). Chick Magnet also had the largest counts and biomass of Coleopterans and Dipterans (Figs. 4.8, 4.10). Araneae counts and biomass were the largest in the Custom Mix (Figs. 4.8, 4.10). Psocopterans were most abundant in wheat fields and least abundant in CRP (Fig. 4.8). Lepidopteran biomass was largest in the wheat fields whereas Orthopteran biomass was largest in CRP fields (Fig. 4.10).

Chemical fallow provided less grass cover and less forb cover but more bare ground than CRP (Figs. 4.11 – 4.13). Chemical fallow provided the least horizontal and overhead visual obstruction (Figs. 4.14, 4.15). CRP provided the most grass cover (59.7% ± 0.6), but Chick Magnet provided the most forb cover (26% ± 0.9; Figs. 4.11, 4.12). Chemical Fallow provided less bare ground that the cover crop treatments (Fig. 4.13). Wheat provided the most bare ground (25.4% ± 1.2; Fig. 4.13). Chemical fallow and CRP had the deepest litter (2.48 cm ± 0.07 and 2.51 cm ± 0.04, respectively; Fig. 4.16). Wheat provided the highest 75% visual obstruction (3.40 dm ± 0.15), followed by CRP (2.73 dm ± 0.06), and then cover crops (Fig. 4.14). Of the cover crop mixes, Chick Magnet provided the least horizontal visual obstruction (1.64 dm ± 0.10; Fig. 4.14). CRP proved more overhead cover based on light interception (47.9 kLux ± 1.0) than wheat (42.4 kLux ± 1.8; Fig. 4.15). Chick Magnet provided the least overhead cover of the cover crop mixes (23.6 kLux ± 1.1; Fig. 4.15).

Discussion

Declines of grassland birds in agricultural landscapes have been linked to pesticide use and habitat fragmentation (Stanton et al. 2018). Cover crop mixes provide more invertebrates for forage and additional cover than traditional chemical fallow. In addition to benefiting wildlife, producers also receive numerous benefits, including increased organic matter, nitrogen fixing, soil nutrient movement, reduced weeds, and reduced soil compaction and erosion (Villami et al. 2006, Wayman et al. 2014, Ladoni et al. 2016). Large-scale conversion of barren chemical fallow fields to spring cover crop fields may mitigate some of the negative influence of intensive row-crop agriculture on grassland birds by providing additional invertebrates and connecting fragmented wildlife habitat. With continuing declines in bird diversity and numbers in agricultural landscapes, it is unclear if remaining habitat patches function as population sinks. Connecting struggling populations and increasing resources available to individuals may alter population demography and convert population sinks to sources.

Cover crops provide a unique combination of vegetation and invertebrates on the landscape. When compared to chemical fallow, all of the cover crops blends tended to provide more cover and more invertebrates. Among the cover crop seed mixes, Chick Magnet tended to provide the most invertebrates but the least amount of vegetation cover, except for forbs. The mix successfully attracts a large quantity of invertebrates, one of the goals of its design. GreenSpring and the custom mix, though providing more cover than Chick Magnet, often fell short of CRP cover and wheat fields cover. Invertebrate surveys were conducted the month before wheat harvest, when wheat was at its peak growth. Cover crops are terminated before they are able to reach their peak growth, which may explain why cover crops provided less overhead cover, shorter vegetation, and fewer of some invertebrate orders compared to CRP and wheat fields. Cover crop fields were surveyed before and after chemical termination. They continued to provide cover and invertebrates even after termination, increasing their duration of influence on local wildlife. Cover crop fields often more closely resembled CRP than chemical fallow. Cover crops provided greater percentages of forb cover and bare ground and greater total invertebrate counts than CRP. CRP provided greater invertebrate richness, greater percentages of grass cover, greater visual obstruction and greater overhead cover. Cover crops provide additional vegetation and invertebrate resources that are different from the existing patch types.

Pheasant selectively used spring cover crop blends for adult and brood locations (Chapters 2, 3). Adults selected cover crop fields consistently over chemical fallow treatments (Chapter 3). Of the cover crop blends, selection rankings and ratios were greatest for GreenSpring over the other cover crop mixes. Greater than 25% of brood locations were associated with cover crops, though cover crops comprised ≤5% of the landscape (Chapter 2). Custom mixes containing grasses and forbs comprised 58% of the cover crop brood locations, compared to 17% in the forb-only blend, Chick Magnet. Of the cover crop mixes, Chick Magnet differed the most from CRP, our positive habitat control and most resembled chemical fallow, our negative control.

The influence of cover crops was not limited to influence pheasant habitat selection but also influenced survival (Chapter IV). Pheasants with cover crops within their home ranges had greater population growth rates than pheasants without cover crops in their home ranges. Adult mortalities were limited during the late breeding season, so cover crops may have more of an influence on brood success than adult survival. Even small amounts of coverage by cover crops has the potential to influence pheasant populations. Pheasants had from 0 - 50% of their home range within cover crops when cover crops comprised very little of the study areas. Pheasants selected for cover crops and benefited from their presence on the landscape.

Spring cover crops have the potential to alter agricultural landscapes to increase the health of local wildlife populations. Large tracts of land are fallow every year, providing little or no resources to wildlife, including pheasants. Planting cover crops will benefit the landowner and local grassland species. Cover crop fields may not only provide additional resources, but may also increase connectivity and help stabilize local wildlife populations (Turner and Gardner 2015).

Management Implications

Spring cover crop mixes resembling CRP, similar to GreenSpring and Custom mixes, will provide additional resources for grassland bird species. Alternative “wildlife-friendly” seed mixes that incorporate both grass and forb components will promote use by pheasants and other wildlife species by more closely mimicking CRP patches. Efforts to incorporate spring cover crops into the crop rotation pattern should start on public lands to provide living examples of cover crop fields. Expanding outwards from public areas, conversion of 5% of the landscape to cover crop coverage within the area of focus through financial incentives and information campaigns will have positive effects on local grassland bird species.

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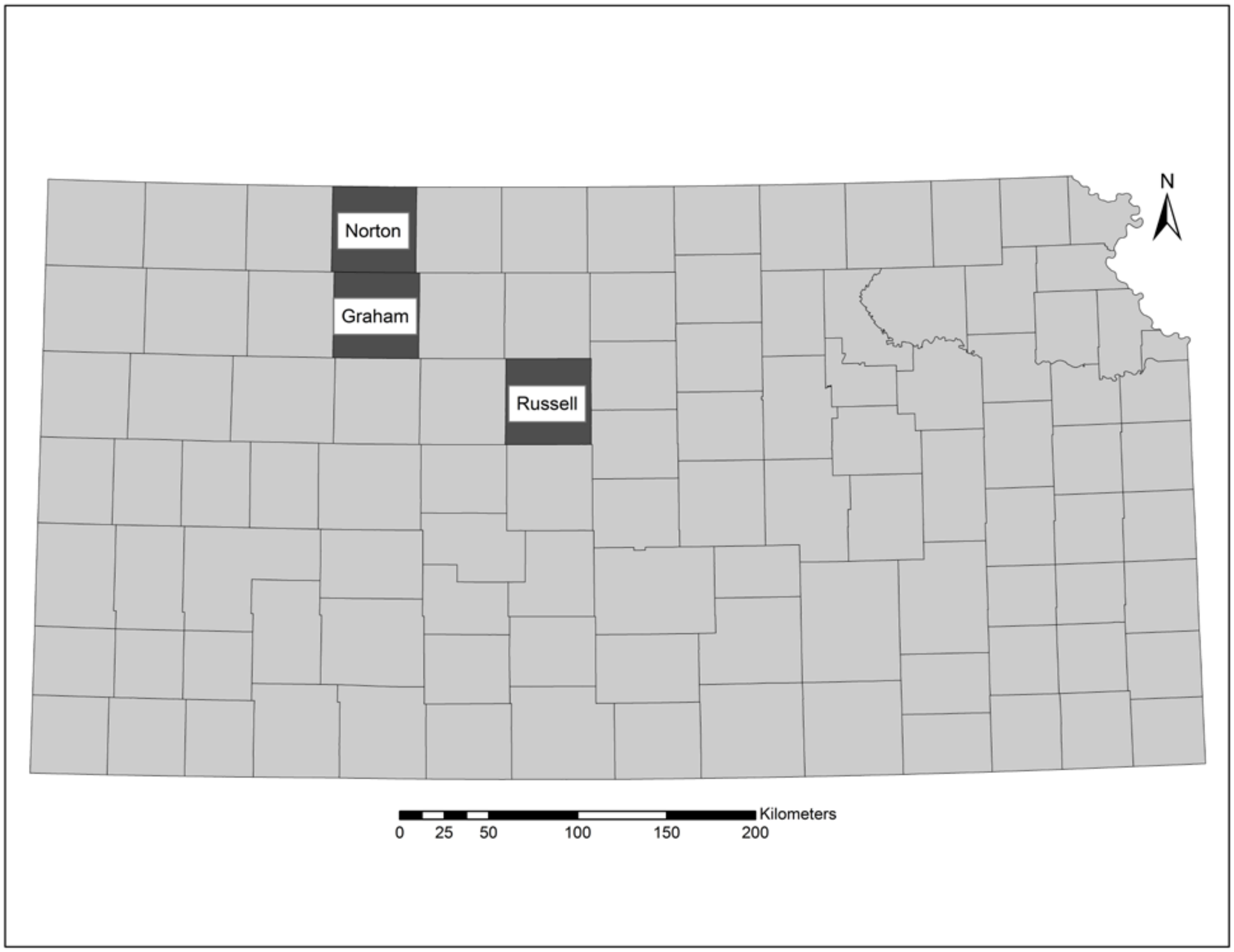

Figure 4.1. Kansas counties containing the study areas in 2017–2019, Graham, Norton, and Russell, in dark grey.

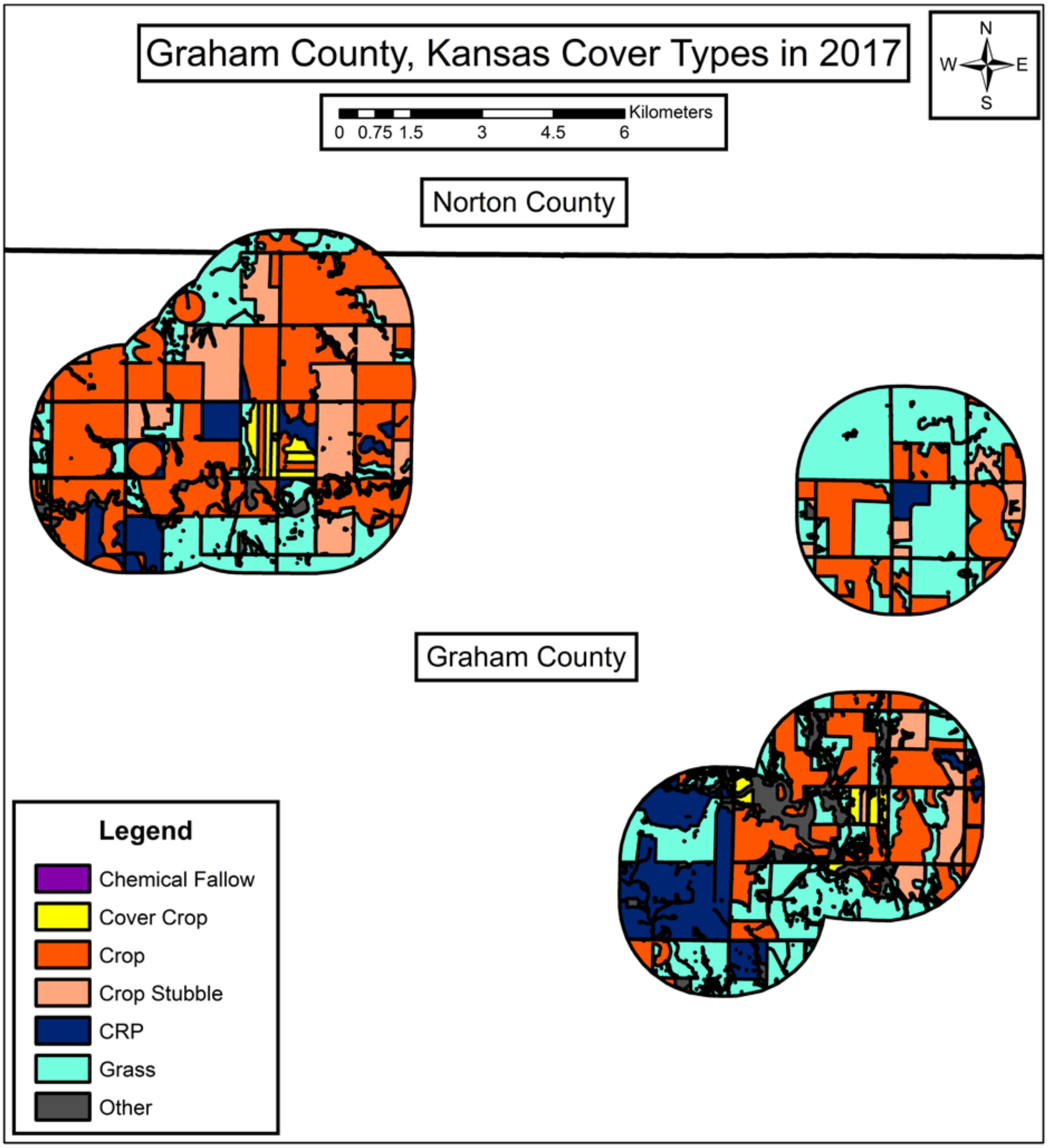

Figure 4.2. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2017 in Graham County, Kansas, USA.

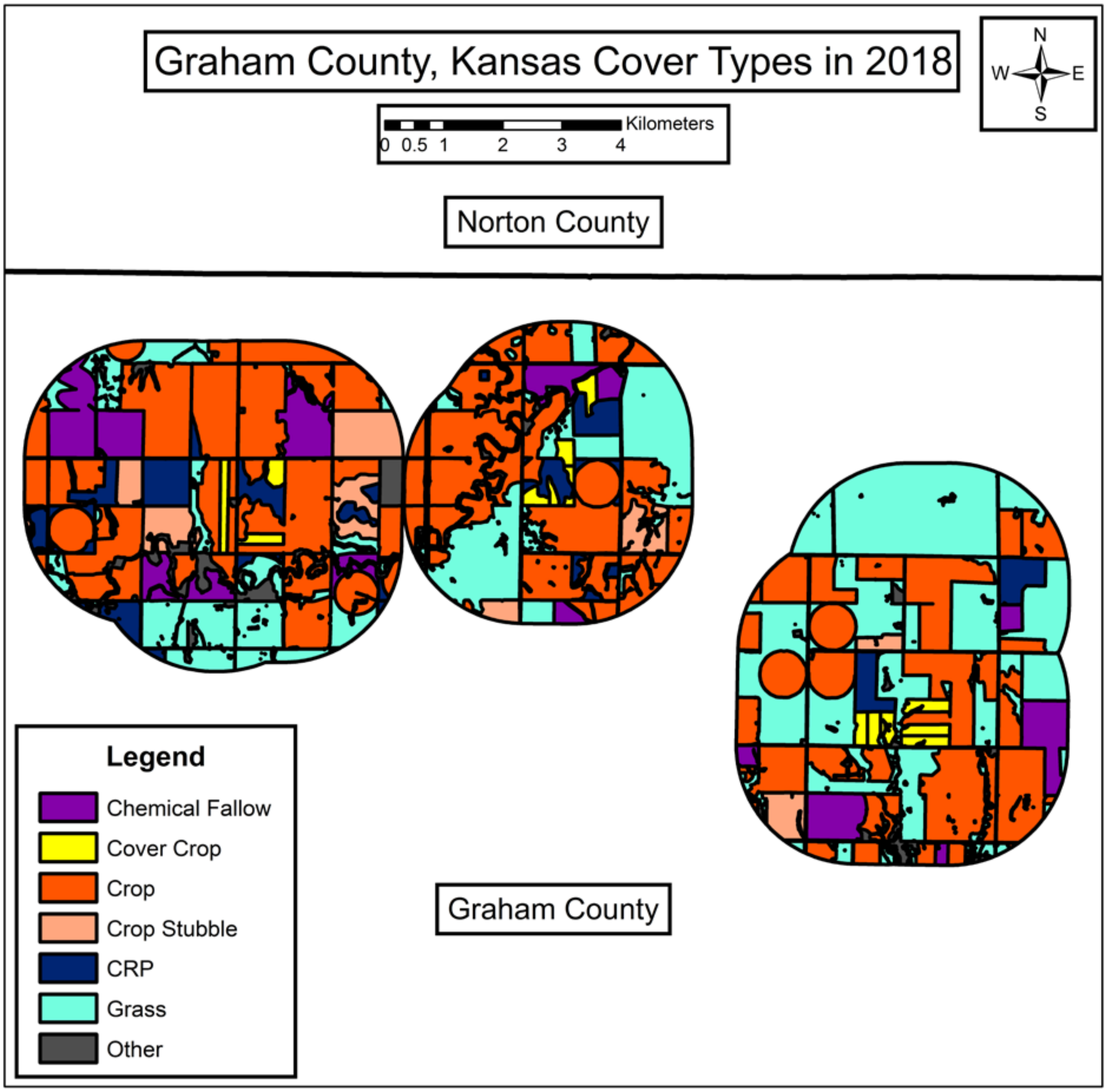
Graham County, Kansas Cover Types in 2018
N
W
E
S
Kilometers
0 0.5 1 2 3 4
Norton County
Graham County
Legend
Chemical Fallow
Cover Crop
Crop
Crop Stubble
CRP
Grass
Other

Figure 4.3. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Graham County, Kansas, USA.

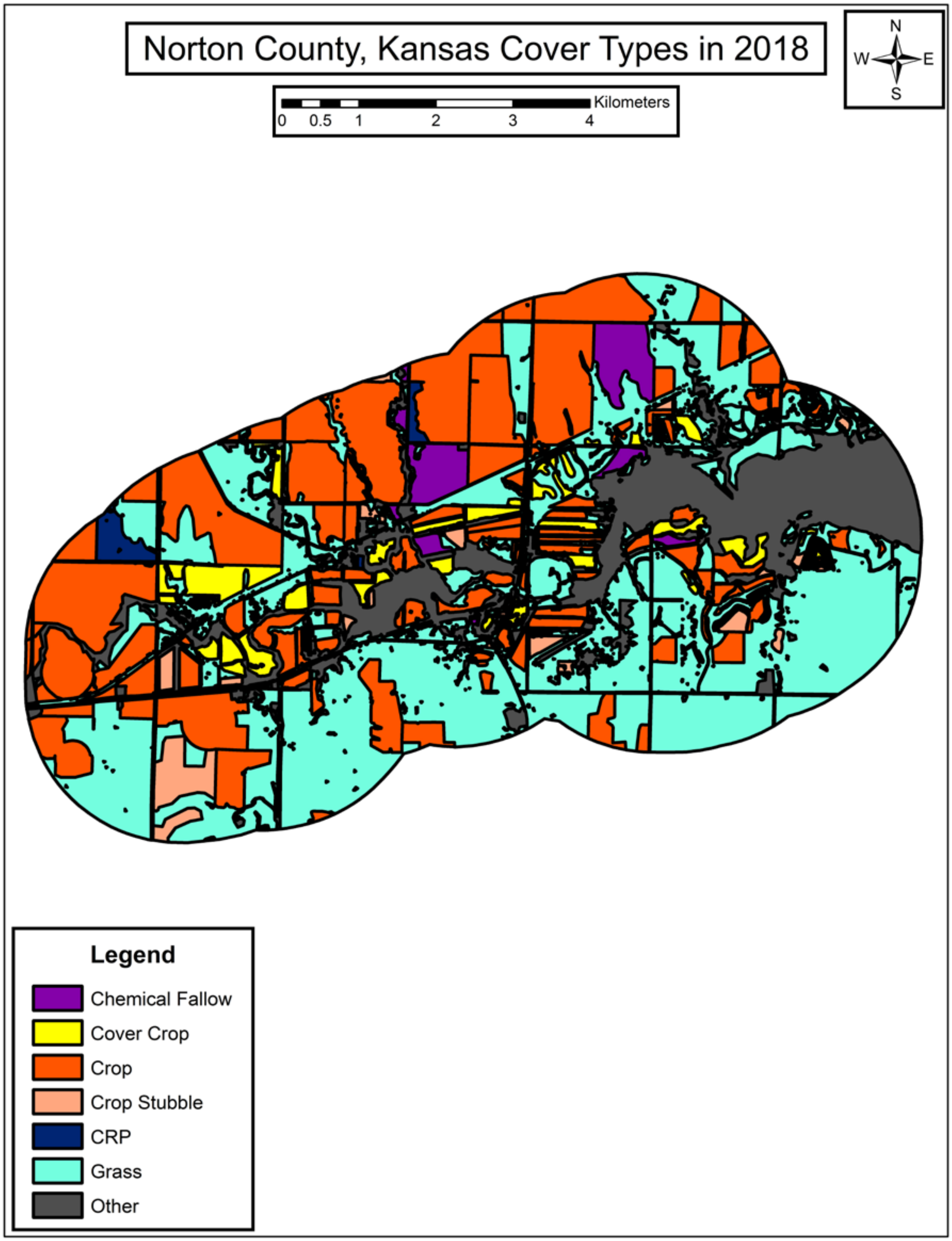

Figure 4.4. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Norton County, Kansas, USA.

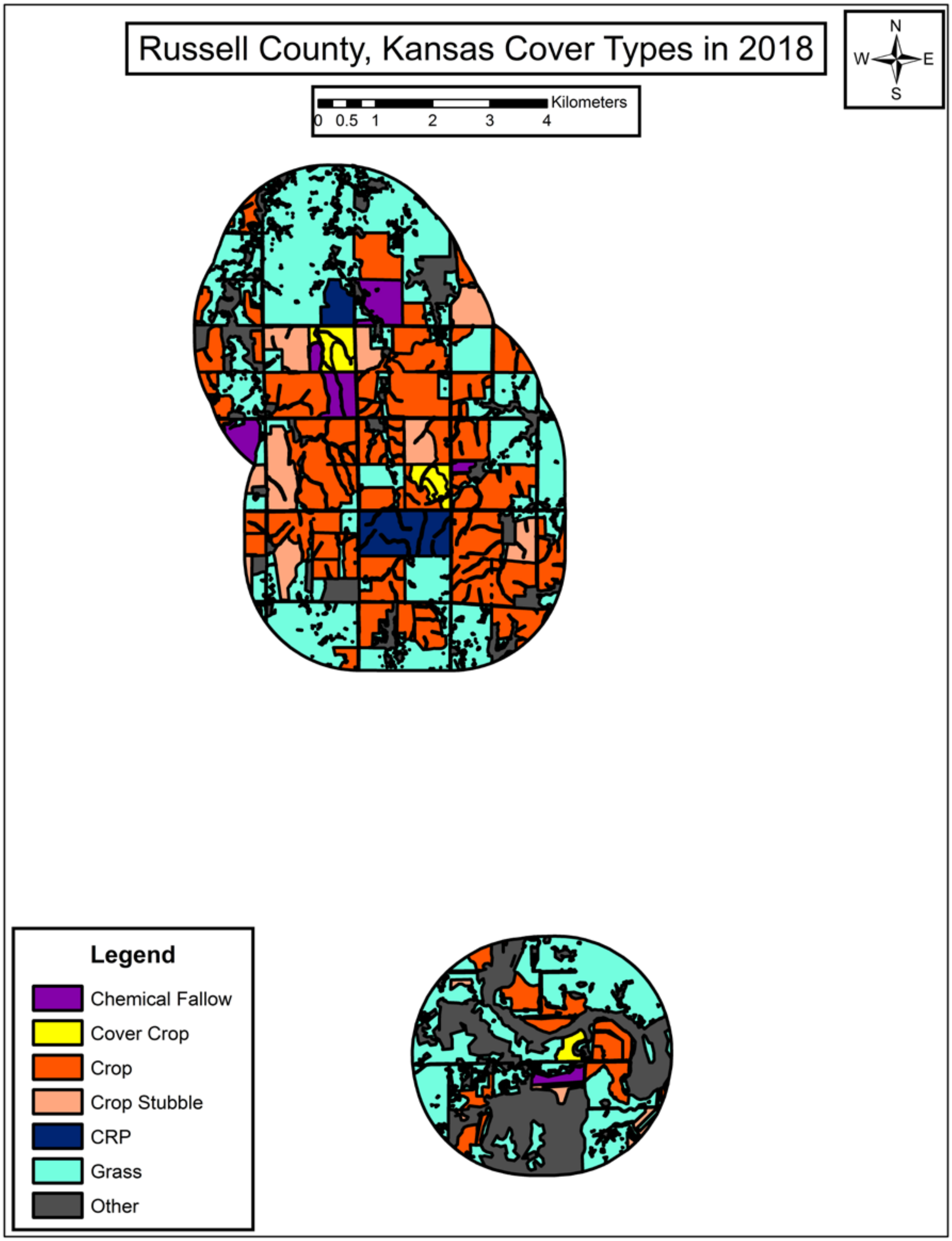

Figure 4.5. Study area cover types delineated based on National Agriculture Imagery Program (NAIP; Farm Service Agency, Salt Lake, UT, USA) imagery and confirmed with in-person visits during the summer of 2018 in Russell County, Kansas, USA.

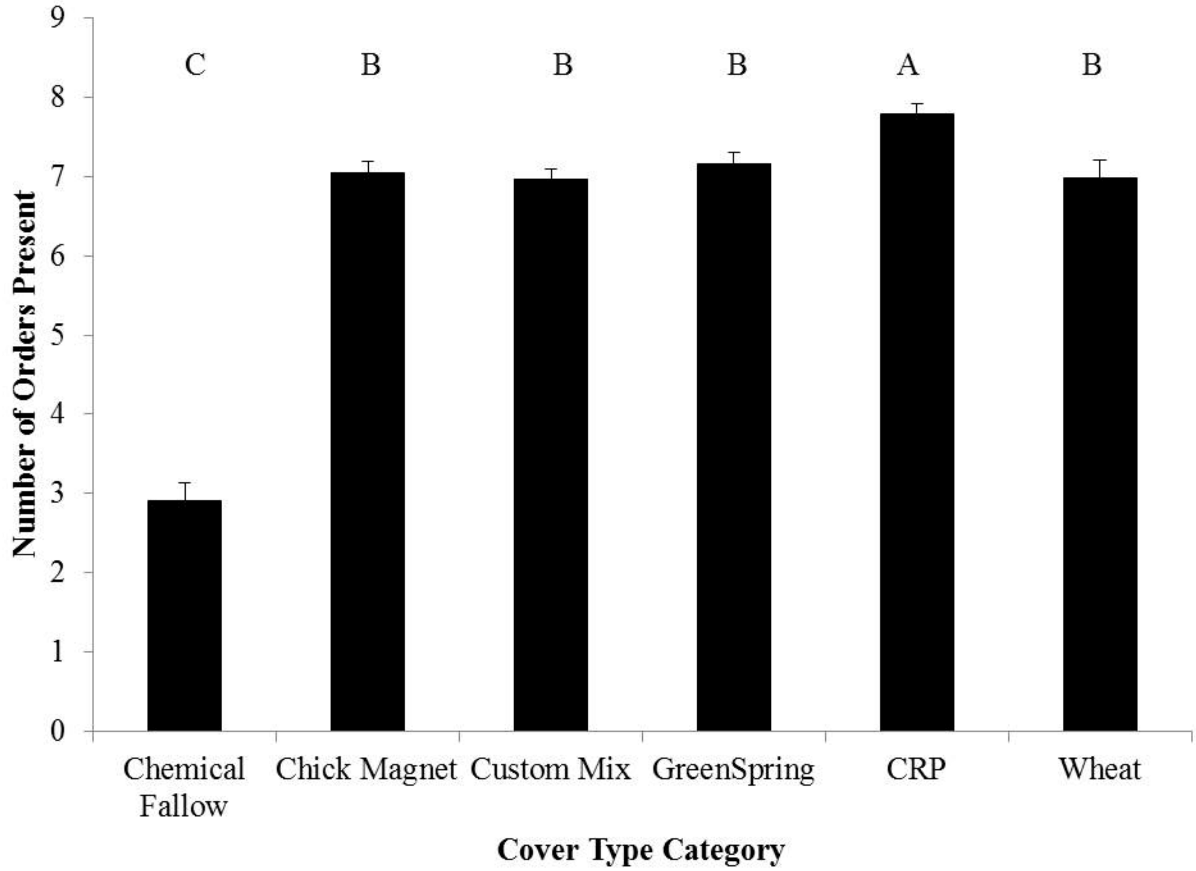

Figure 4.6. Average number of invertebrate orders present in a 100-m sweep transect at a randomized location within a treatment field, in Graham County, Kansas, USA, in June 2017 (n = 382). Fifteen total orders were detected. Error bars represent the standard error. Means depicted by the same uppercase letter do not differ ($P \leq 0.05$).

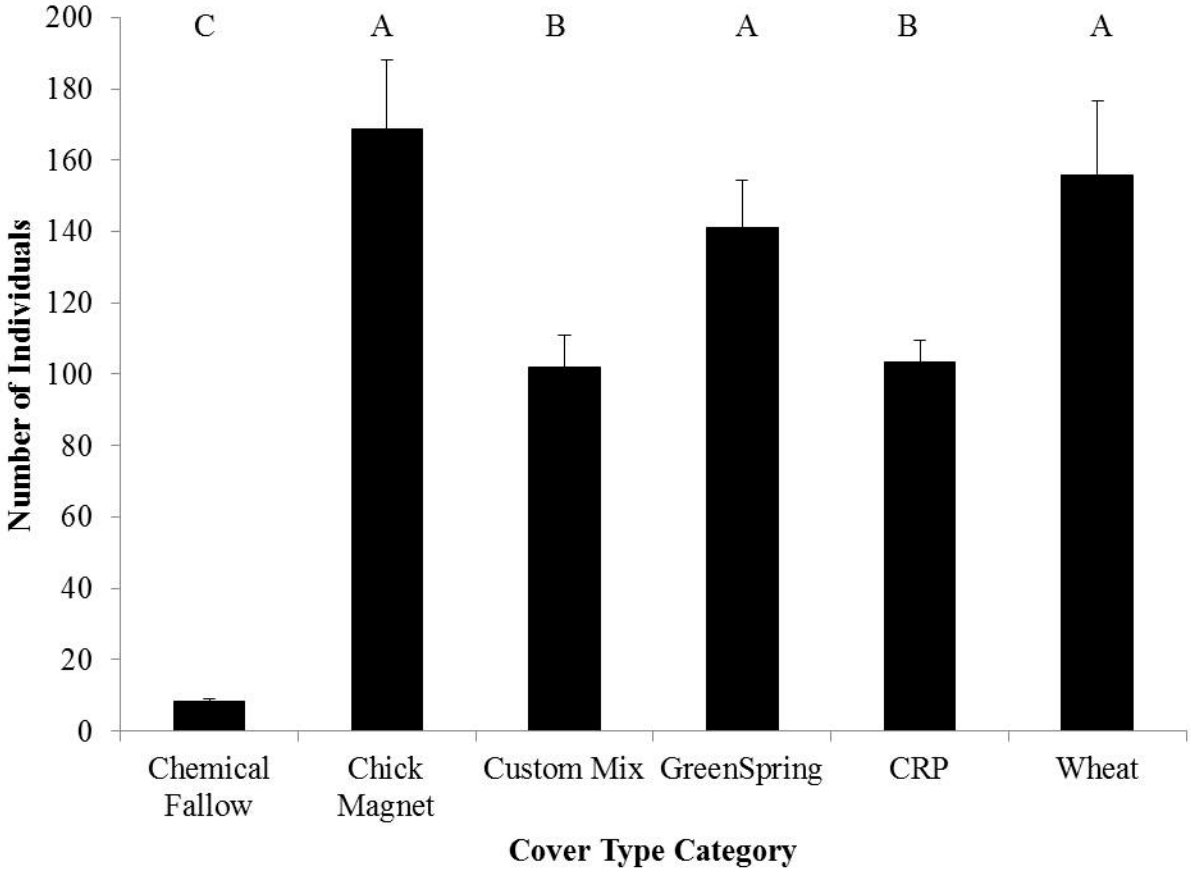

Figure 4.7. Average number of invertebrates present in a 100-m sweep transect at a randomized location within a treatment field, in Graham County, Kansas, USA, in June 2017 (*n* = 382). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ ($P \leq 0.05$).

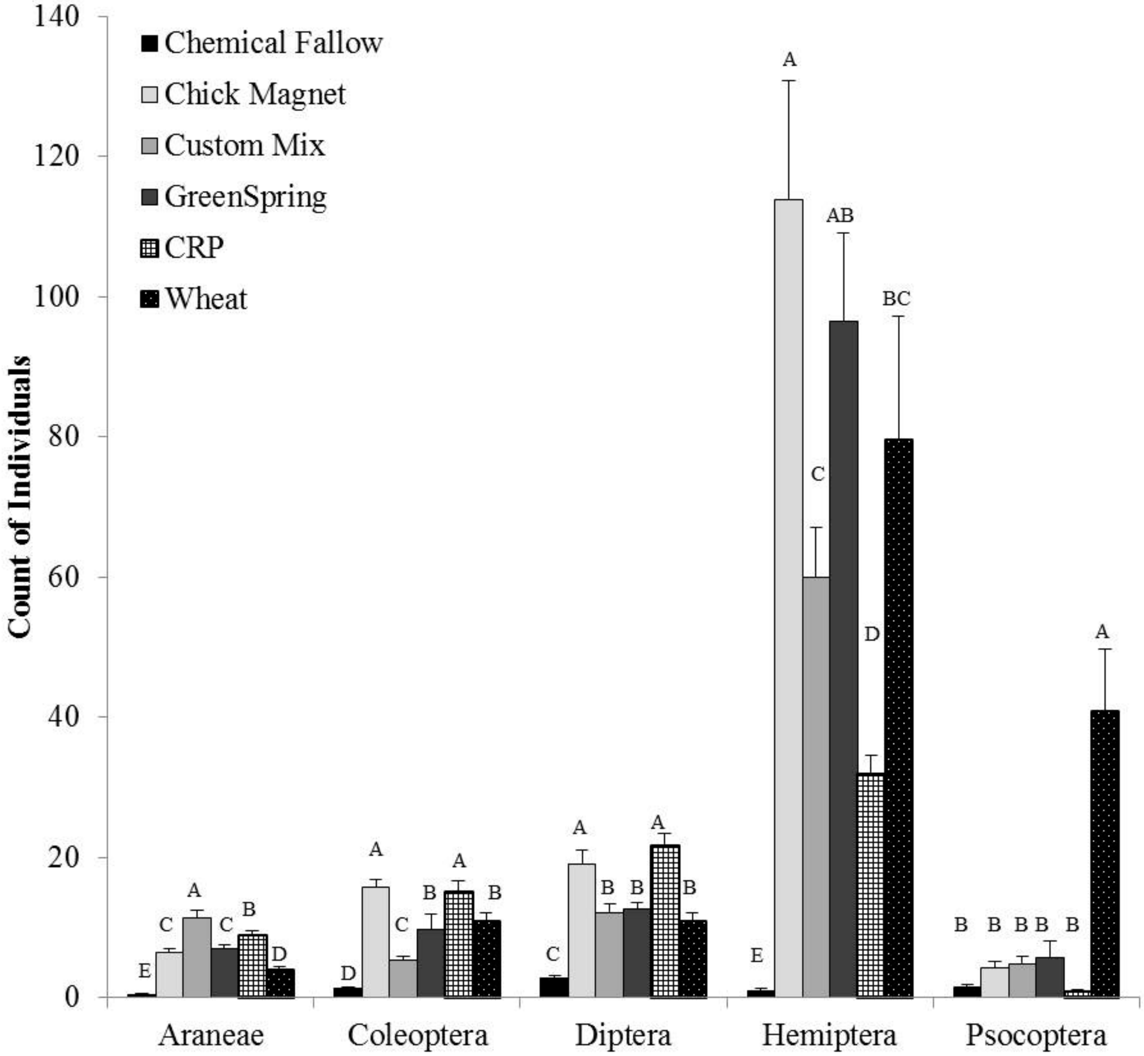

Figure 4.8. Average number of invertebrates within orders comprising ≥10% of the total count in a 100-m sweep transect at a randomized location within a treatment field, in Graham County, Kansas, USA, in June 2017 (*n* = 382). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ (*P* ≤ 0.05).

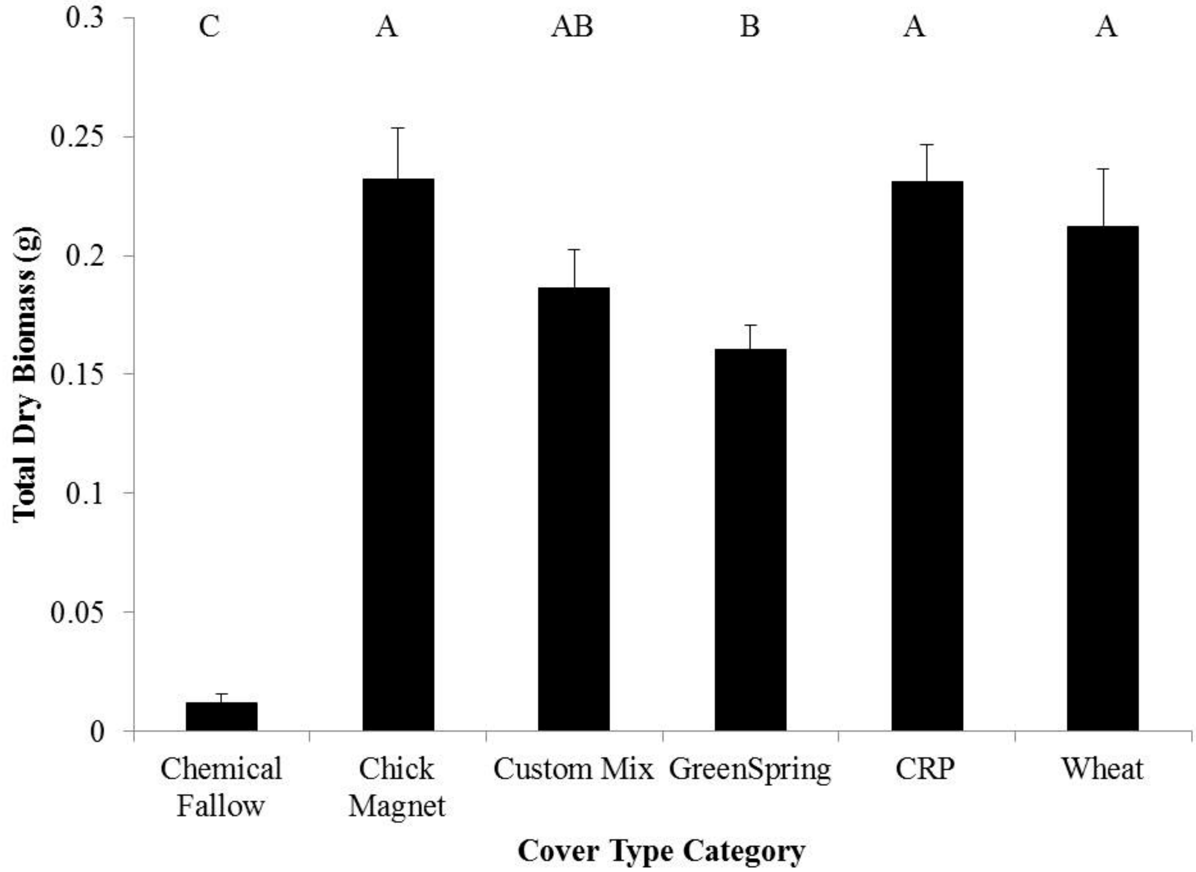

Figure 4.9. Average dry biomass of invertebrates present in a 100-m sweep transect at a randomized location within a treatment field, in Graham County, Kansas, USA, in June 2017 (n = 382). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ t ($P \leq 0.05$).

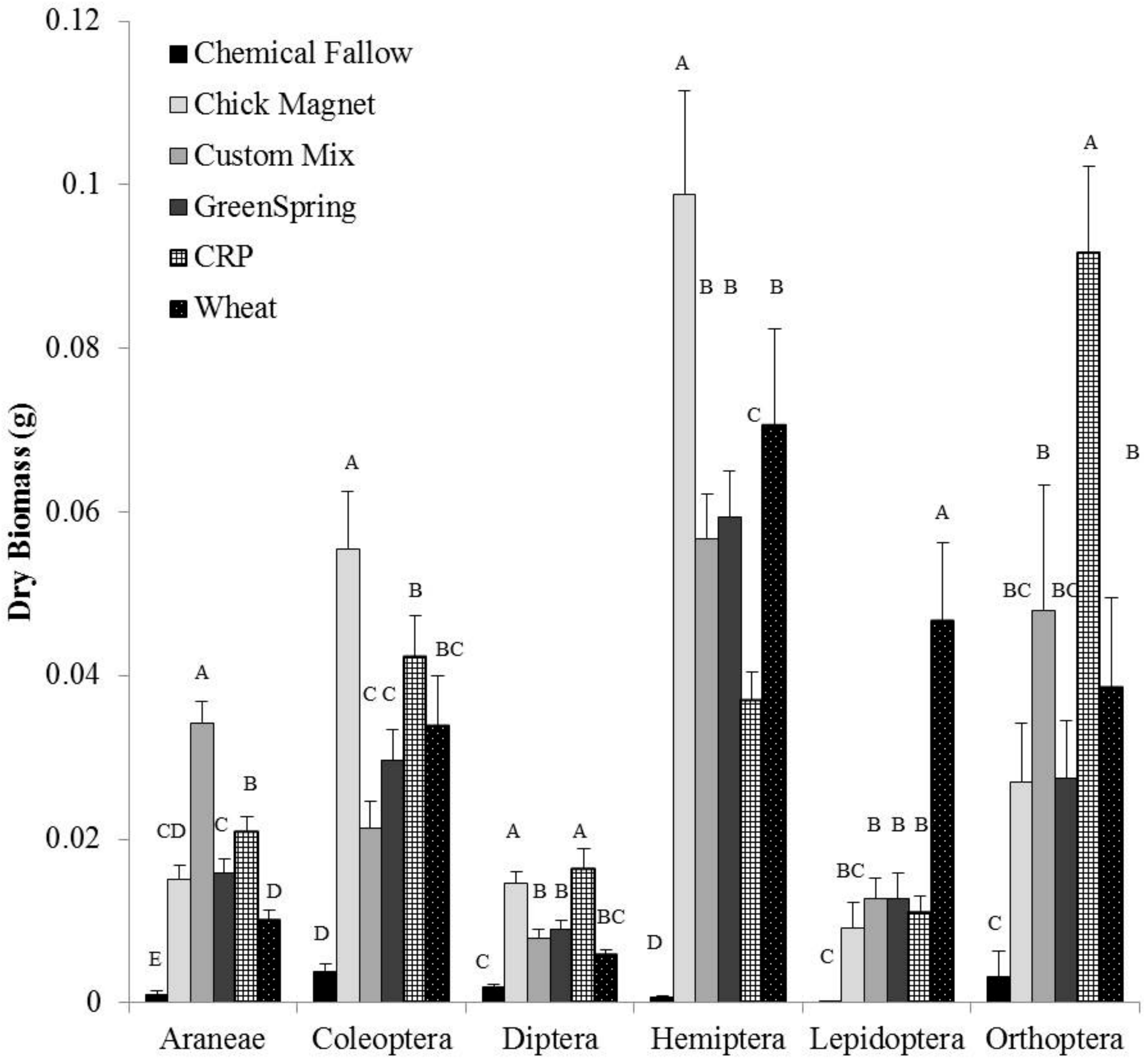

Figure 4.10. Average dry biomass of invertebrates present in a 100-m sweep transect at a randomized location within a treatment field within orders comprising ≥10% of the total dry biomass, in Graham County, Kansas, USA, in June 2017 (*n* = 382). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ (*P* ≤ 0.05).

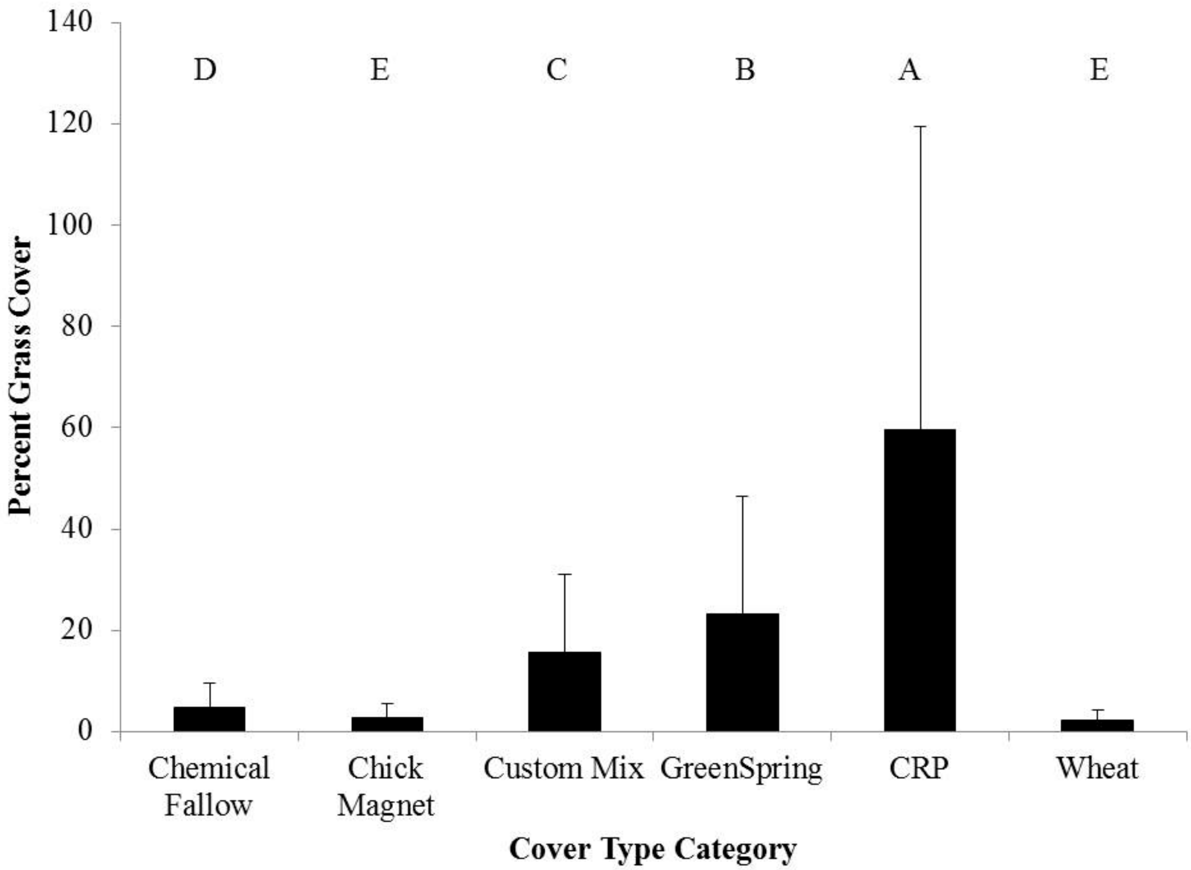

Figure 4.11. Average percent grass in a 60-cm Daubenmire frame at a randomized location within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (*n* = 3,316). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ (*P* ≤ 0.05).

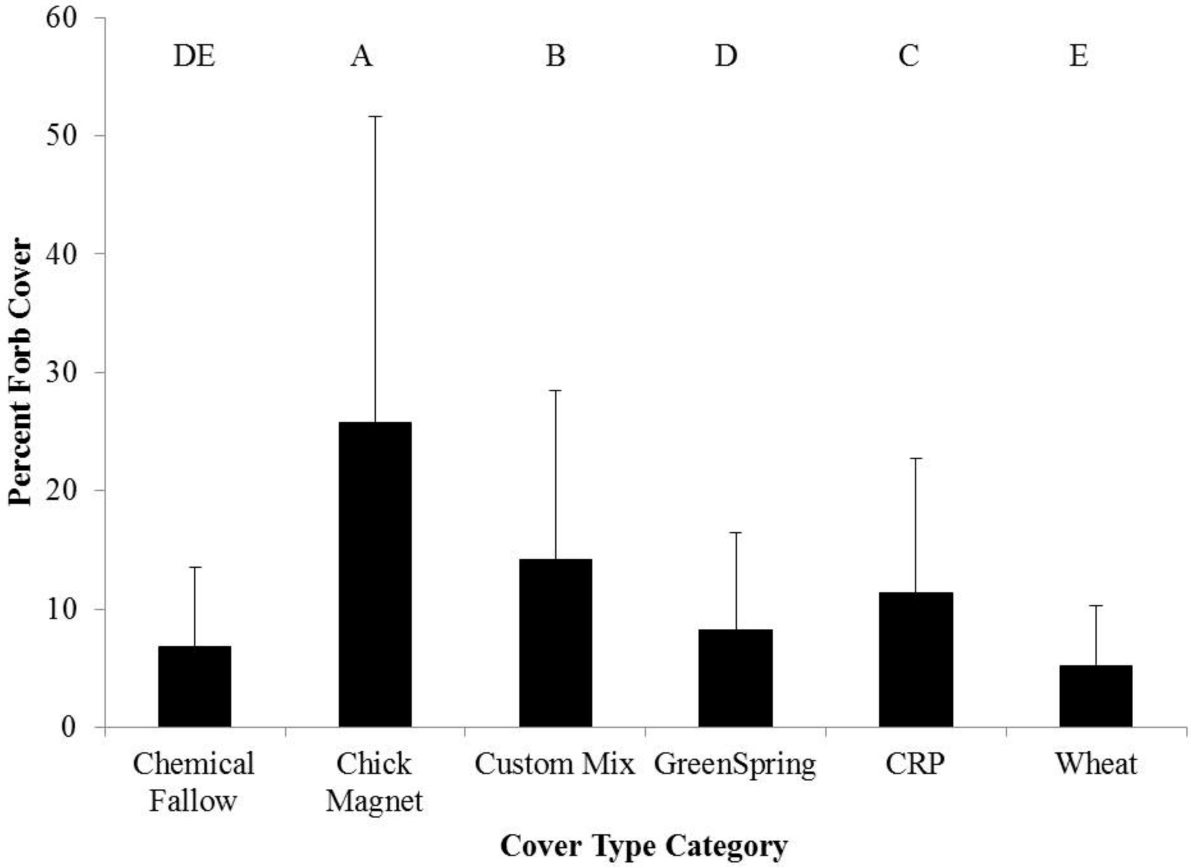

Figure 4.12. Average percent forb in a 60-cm Daubenmire frame at a randomized location within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (*n* = 3,316). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ (*P* ≤ 0.05).

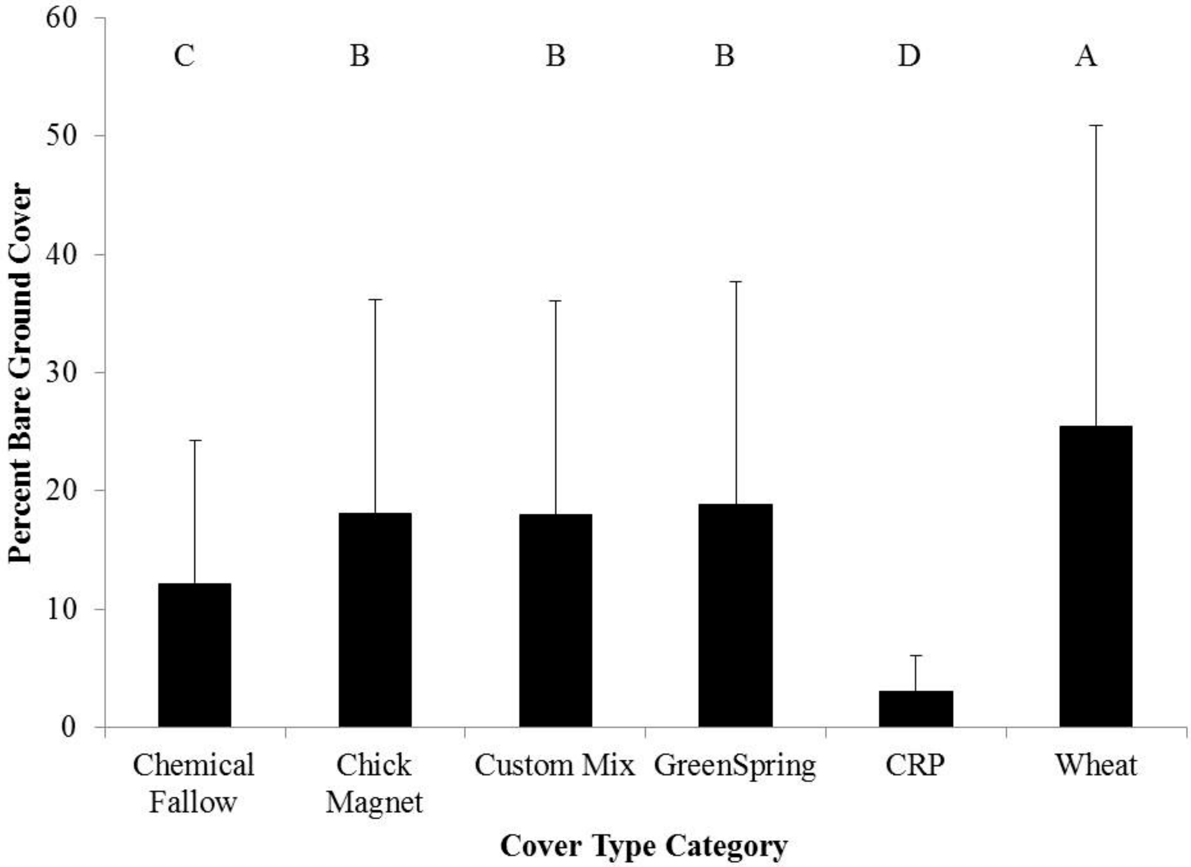

Figure 4.13. Average percent bare ground in a 60-cm Daubenmire frame at a randomized location within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (*n* = 3,316). Means depicted by the same uppercase letter do not differ ($P \leq 0.05$).

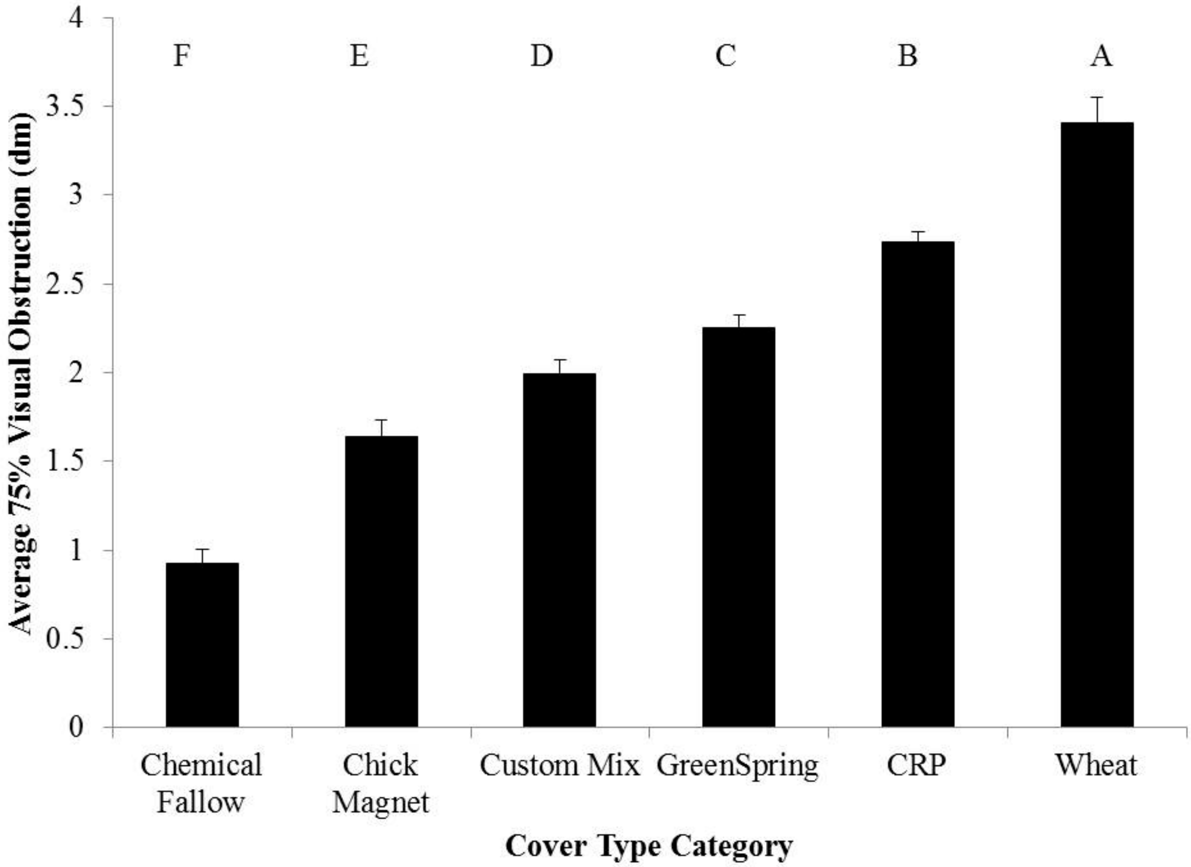

Figure 4.14. Average 75% Visual Obstruction Reading (dm) at random locations and 4 m away from the location at each cardinal direction within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (*n* = 3,316). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ (*P* ≤ 0.05).

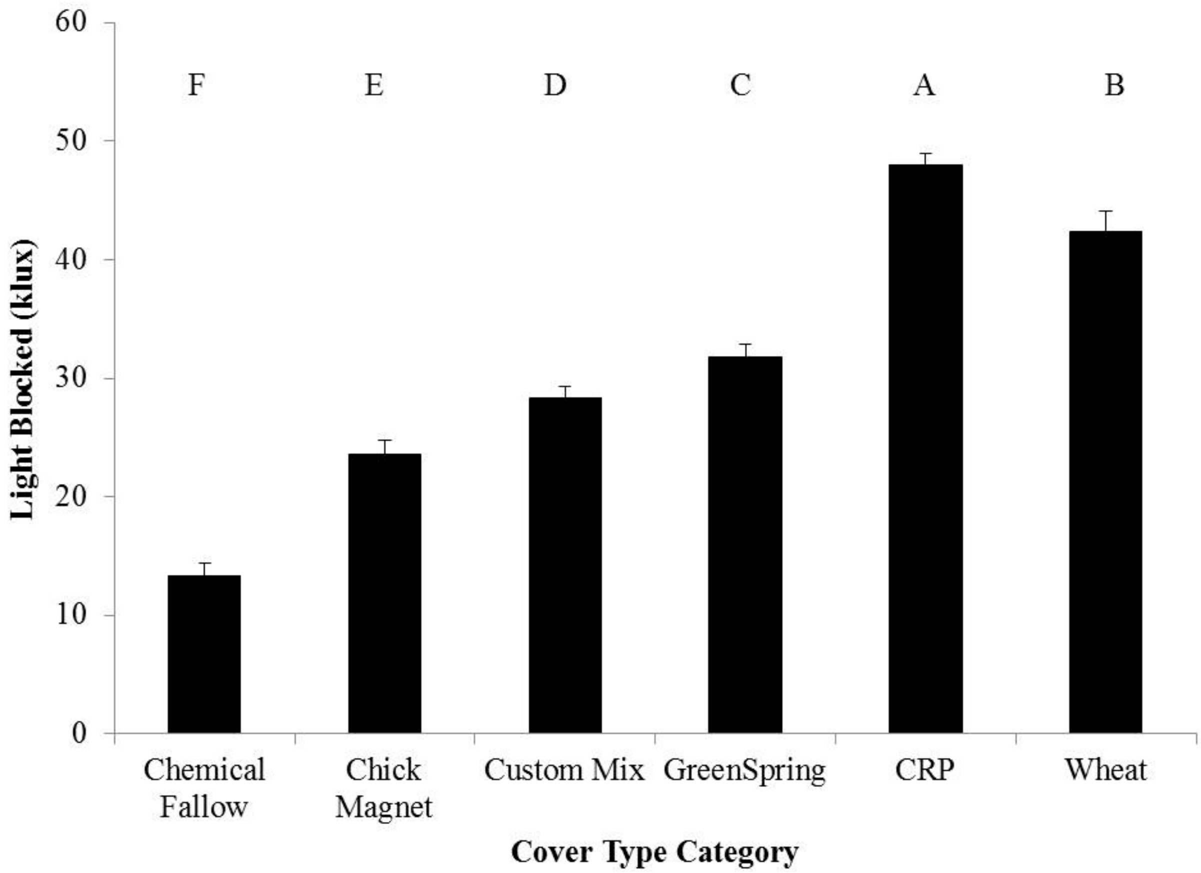

Figure 4.15. Average overhead vegetation, measured by light blocked by vegetation, at a randomized location within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (n = 3,316). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ ($P \leq 0.05$).

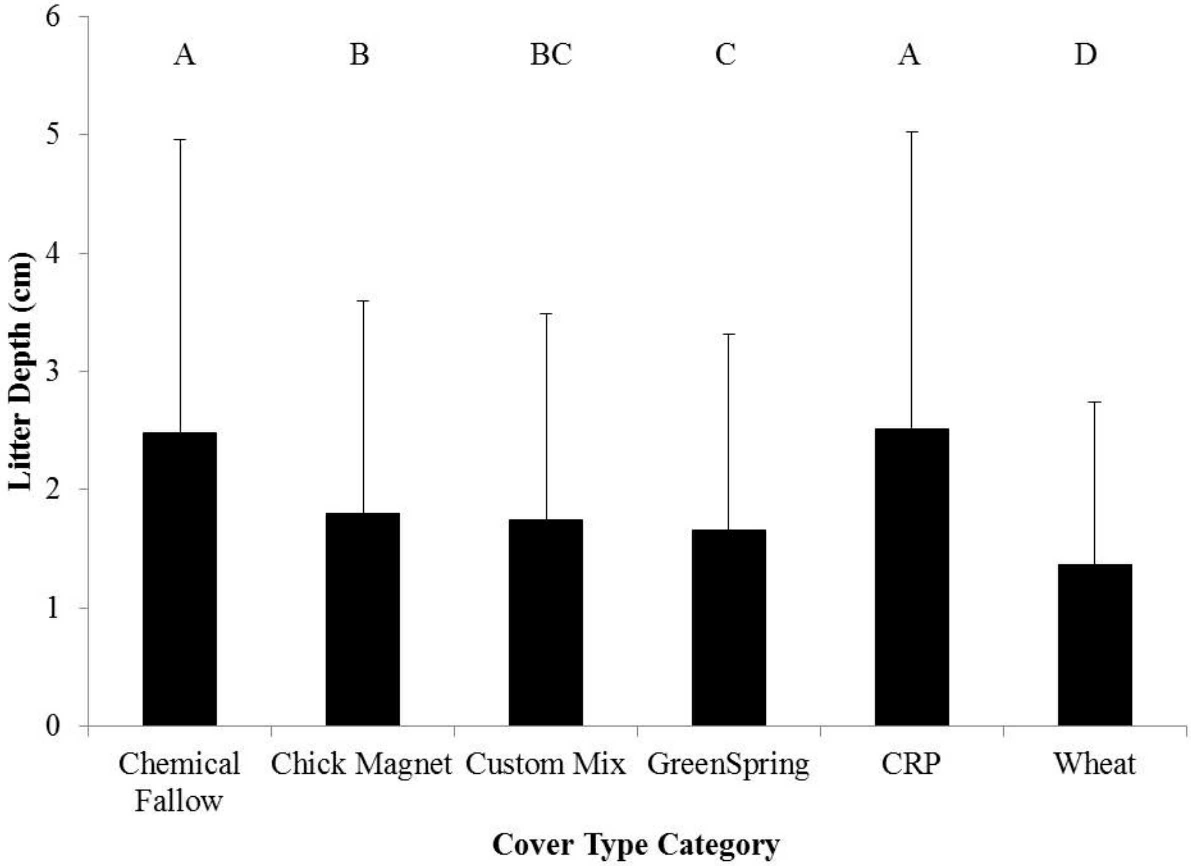

Figure 4.16. Average litter depth (cm) at a randomized location within a treatment field May 7 – August 7, in Graham, Norton and Russell counties, Kansas, USA, 2017 – 2019 (*n* = 3,316). Error bars represent the standard error. Means depicted by the same uppercase letter do not differ ($P \leq 0.05$).

Table 4.1. Summary of study field sizes and coverage within the study areas in western Kansas, USA, 2017–2018, including spring cover crop treatment fields, chemical fallow negative control, Conservation Reserve Program positive control, and the dominant cover type of active wheat fields. Cover crop mixes include GreenSpring© (73 kg/ha), Chick Magnet© (28 kg/ha), and a Custom Wildlife Mix (41 kg/ha) developed by Star Seed Company (Osbourne, KS, USA).

	2017			2018		
Treatment	Average Field Size	# Treatments	Total Area	Average Field Size	# Treatments	Total Area
			Graham County			
Chemical Fallow	15.2	3	45.5	18.2	3	54.7
Chick Magnet	16.8	3	50.4	13.1	4	52.4
Custom Mix	16.9	3	50.5	15.3	4	61.2
GreenSpring	16.7	3	50.0	13.2	4	52.8
CRP	45.6	4	182.2	45.1	4	180.5
Wheat	123.4	2	246.8	23.2	1	23.2
			Norton County			
Chemical Fallow	N/A	N/A	N/A	9	2	35.8
Chick Magnet	N/A	N/A	N/A	4.7	2	37.5
Custom Mix	N/A	N/A	N/A	8.5	2	34.1
GreenSpring	N/A	N/A	N/A	6.8	2	27.2
CRP	N/A	N/A	N/A	11.9	2	23.7
Wheat	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.1 continued.

Treatment	2017			2018		
	Average Field Size	# Treatments	Total Area	Average Field Size	# Treatments	Total Area
Russell County						
Chemical Fallow	N/A	N/A	N/A	26.9	2	53.9
Chick Magnet	N/A	N/A	N/A	14.9	2	29.9
Custom Mix	N/A	N/A	N/A	13.8	2	27.7
GreenSpring	N/A	N/A	N/A	14.8	2	29.6
CRP	N/A	N/A	N/A	82.3	2	164.5
Wheat	N/A	N/A	N/A	20.8	1	20.8
All Counties						
Chemical Fallow	15.2	3	45.5	18.0	7	144.4
Chick Magnet	16.8	3	50.4	10.9	8	119.8
Custom Mix	16.9	3	50.5	12.5	8	123.0
GreenSpring	16.7	3	50.0	11.6	8	109.6
CRP	45.6	4	182.2	46.4	3	368.7
Wheat	123.4	2	246.8	22.0	2	44.0

Table 4.2. Summary of climate, weather and land cover of study areas in western Kansas, USA, from 2017–2019. Climate data includes long-term averages of annual precipitation totals (mm) and long-term averages of annual average temperature (° C), from 1981–2010 annual normal data at three weather stations (USW00093990-Graham, USC00145852-Norton, USW00093997-Russell). Weather was collected at the same weather stations. Average temperature was calculated by adding the maximum temperature and minimum temperature and dividing by two.

	Graham	Norton	Russell
Average Annual Temperature	11.9	11	12.6
Average Annual Total Precipitation	582.17	656.34	648.46
2017 Average Temperature	13.2	11.8	13.7
2018 Average Temperature	12.0	10.3	13.1
2017 Total Precipitation (mm)	590.0	325.2	439.6
2018 Total Precipitation (mm)	921.2	256.3	795.5