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CORRELATES OF NORTHERN BOBWHITE DISTRIBUTION AND ABUNDANCE WITH LAND-USE CHARACTERISTICS IN KANSAS

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Abstract: County-level agricultural statistics were correlated with Rural Mail Carrier Survey reports and Breeding Bird Survey data for northern bobwhite (*Colinus virginianus*) in Kansas. Results indicate statewide analysis is feasible when temporally congruent data exist for both agricultural land-use characteristics and bobwhite distribution and abundance. Interpretations of these results can be useful in state or regional analysis and in the development of habitat management strategies for bobwhite. The Multiple Response Permutation Procedure identified 16 land-use variables, 3 soil variables, and 1 spatial variable that were significantly different in counties where bobwhite were present from counties where they were absent. Sixteen land-use variables, 5 soil variables, and 3 spatial variables distinguished between counties where bobwhite abundance was classified as high or low. Spearman's rank correlation identified 8 soil variables, 14 land-use variables, and 3 spatial variables that were significantly correlated with bobwhite abundance. Least absolute deviation regression analysis revealed 4 land-use variables that were significantly correlated (Agreement = 0.48, $P = 0.0001$) with bobwhite abundance.

Key words: abundance, agriculture, *Colinus virginianus*, distribution, Kansas, land use, northern bobwhite.

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Recent analyses of Breeding Bird Survey (BBS) (Droege and Sauer 1990) and Christmas Bird Count (Brennan 1991) data indicated long-term declines (>25 years) in northern bobwhite populations in >77% of 31 states. The annual rate of change for the continental United States was -2.4% from 1966 to 1989 (Droege and Sauer 1990). Flather and Hoekstra (1989:36) reported harvest of bobwhite in 13 states declined >50% during the years 1965-85. Likewise, the number of quail hunters declined nationally by 11% between 1980 and 1985 (USDI 1988); and for the first time there were more hunters pursuing ring-necked pheasants (*Phasianus colchicus*) than bobwhite.

Although many factors affect wildlife abundance, land use is often considered the most important determinant of base population levels in agricultural environments (Edwards et al. 1981). For example, Brady (1988) reported declining harvests of bobwhite in Illinois were correlated ($r^2 = 0.67$, $P < 0.0001$) with increasing area of rowcrops over a 30-year period. Thirty years ago bobwhite habitat was primarily a by-product of farming (Klimstra 1982). Today, land-use practices do not provide adequate habitat for bobwhite (Brennan 1991).

Habitat requirements and microhabitat associations of bobwhite have been studied extensively. This information is often used to prescribe management for "local" bobwhite populations on individual farms or wildlife areas (Warner and Etter 1985). However, data are also necessary for landscape level planning to balance the needs of agricultural programs and "regional" wildlife populations (Harmon 1981, Warner and Etter 1985). Therefore, we evaluated county-level agricultural land-use patterns with distribution and relative abundance information for bobwhite in Kansas. Our objectives were to (1) explore the use of 4 existing data sets to describe regional patterns of bobwhite populations relative to agricultural land use and (2) interpret these patterns relative to federal agricultural programs or technologies.

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STUDY AREA AND METHODS

Land-use Information

We used Census of Agriculture (USDC 1976, 1980, 1984, 1989) and National Resources Inventory (NRI; USDA 1984) data to describe county-level agricultural land use and technological applications. Census of Agriculture data were available for all 105 counties in Kansas, while NRI data were available for 47 counties. Census of Agriculture information provided the most accurate estimates of crop types and pesticide use, whereas NRI data provided better descriptions of the sequence of crops over time (crop rotations), soil characteristics, and distances between cover types. Where appropriate, all variables were converted to proportions to control for varying county sizes (Table 1).

Population Indexes

We used Rural Mail Carrier Survey (RMCS) (Wells and Sexson 1982) and BBS (Droege 1990) data to measure distribution and relative abundance of bobwhite in Kansas. The RMCS data were available for all 105 counties, whereas BBS data were available for 36 routes which were then assigned to counties. The RMCS data were gathered incidental to postal delivery by 533 mail carriers driving >435,000 km during a 5-day

Table 1. County-level land use and soil variables from the National Resources Inventory and the Census of Agriculture that were associated with bobwhite distribution and relative abundance in Kansas.

Variable	Description
National Resources Inventory	
% LCC1	% of county in Land Capability Class 1
% LCC2	% of county in Land Capability Class 2
% LCC3	% of county in Land Capability Class 3
% LCC4	% of county in Land Capability Class 4
% LCC5	% of county in Land Capability Class 5
% prime farmland soils	% of county in prime farmland soils
% grazed	% of county grazed by livestock
% cropland	% of county in agricultural crops
% soybeans	% of county in soybeans
% wheat	% of county in wheat
% pasture	% of county in pasture
% woodland	% of county in woodland
% meadow	% of county in hay
% small water bodies	% of county occupied by small water bodies
Mean distance to cropland	Mean distance from randomly selected points to the nearest occurrence of cropland
Mean distance to grassland	Mean distance from randomly selected points to the nearest occurrence of grassland
Mean distance to water	Mean distance from randomly selected points to the nearest occurrence of surface water
Erodibility index (water)	Potential erodibility based on the Universal Soil Loss Equation (Wischmeier and Smith 1978)
Erodibility index (wind)	Potential erodibility based on the Wind Erosion Equation
R factor	Rainfall and runoff factor, measure of the duration and intensity of rainfall used in the Universal Soil Loss Equation
T factor	Tolerable soil loss level or the rate of soil erosion that can occur without degrading the productive capacity of the soil
Length of slope	Length of the effective slope that water will run off as sheet flow before becoming concentrated flow
% slope	The vertical height (rise) of a hillside divided by the horizontal length (run), expressed as a percent
LS factor	Index that compares the soil loss from the field length and percent of slope to a standard unit (9%, 22.1 m)

Table 1 (cont.).

Variable	Description
Census of Agriculture	
% diverted crops	% of county where cropland was enrolled in USDA wheat or feed-grain set-aside programs
% cover crops	% of county where cover crops were planted for soil protection or enhancement
% herbicides	% of county treated with herbicides
% insecticides	% of county treated with insecticides
% nematicides	% of county treated with nematicides
% sorghum	% of county in sorghum
% oats	% of county in oats
Hogs/ha	Number of hogs in the county divided by the area of the county
Cows/ha	Number of cattle in the county divided by the area of the county
% farmland	% of county classified as farmland
% soybeans	% of county in soybeans
% wheat	% of county in wheat
% pasture/range fertilized	% of county in pasture or rangeland and where fertilizers were applied
% woodland	% of county in woodland
% hay	% of county in hay
% alfalfa	% of county in alfalfa
% hay (except alfalfa)	% of county in hay crops other than alfalfa
% wild hay	% of county in native hay (naturally occurring grasses and forbs)
Average farm size	Average size of farms in the county

period in April 1982. These data were expressed as an index of the number of bobwhite observed per 161 km. Bobwhite were categorized in each county as: (1) present or absent and (2) low-density (<1.425/161 km) or high-density (≥1.425/161 km).

The BBS data were obtained for 1967-88. Trained volunteers count birds on these routes under optimal environmental conditions during May. Birds are recorded at a series of 50 3-minute stops during early morning. We used the relative ranking of BBS routes by bobwhite abundance rather than the absolute values of population estimates (Droege 1990, Geissler and Sauer 1990) for the correlations.

Analysis Procedures

The nonparametric Multiple Response Permutation Procedure (MRPP) (Mielke et al. 1976, Slauson et al. 1991) was used to test among discrete categories of bobwhite distribution (present/absent) and abundance (low/high) and land-use variables. The null hypothesis was that land-use characteristics were identical among categories.

Spearman's rank correlation test (Conover 1971:245) was used to test among continuous variables of bobwhite abundance with land use as well as to correlate RMCS and BBS data with each other. Least Absolute Deviation (LAD) regression (Slauson et al. 1991) was used to determine the relationship of land-use variables to bobwhite abundance. LAD regression variables were selected iteratively to achieve the combination of variables that gave the best fit model. Where concurrent data existed, we examined temporal relationships by correlating the slopes of trend lines from BBS routes (1967-88) with the slopes of the trend lines from agricultural land uses during the years 1974, 1978, 1982, and 1987 (USDC 1976, 1980, 1984, 1989) for each county.

RESULTS

Distribution and Abundance

Northern bobwhite were reported by rural mail carriers in 90 of 105 counties in 1982 (Fig. 1). The mean number of bobwhite per 161 km was 3.1 (SE = 0.32, median = 1.6, range = 14.4). Thirty-two counties were classified as low-density and 58 as

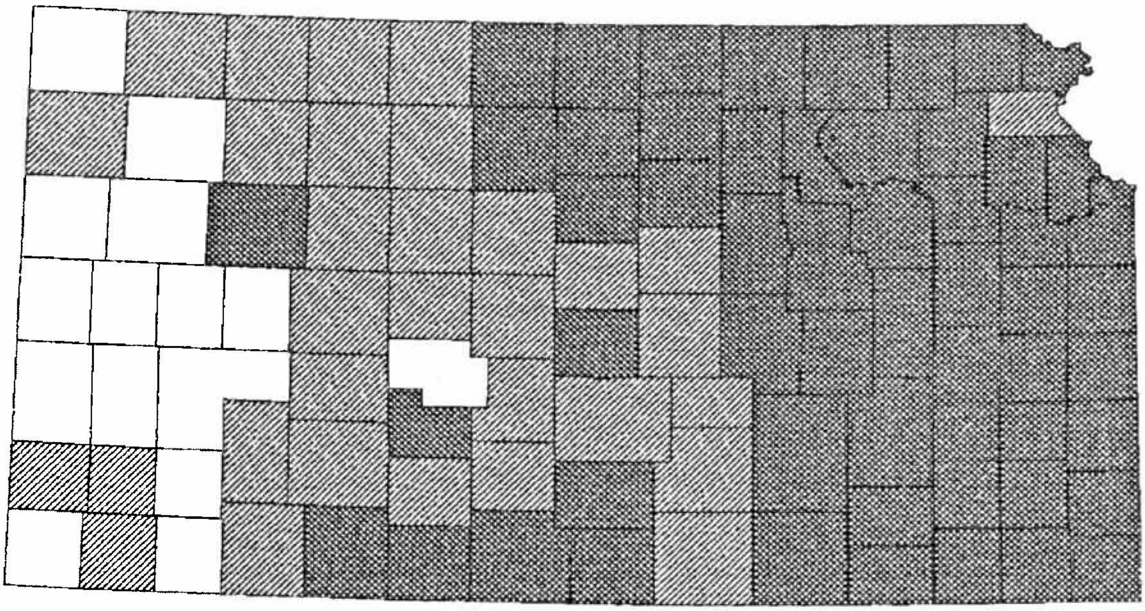

Fig. 1. Distribution and relative abundance of bobwhite in Kansas determined from Rural Mail Carrier Survey data. Crosshatching indicates high bobwhite abundance (≥ 1.425 birds/161 km) and diagonal lines indicate low abundance. Bobwhite were not observed in the unmarked counties.

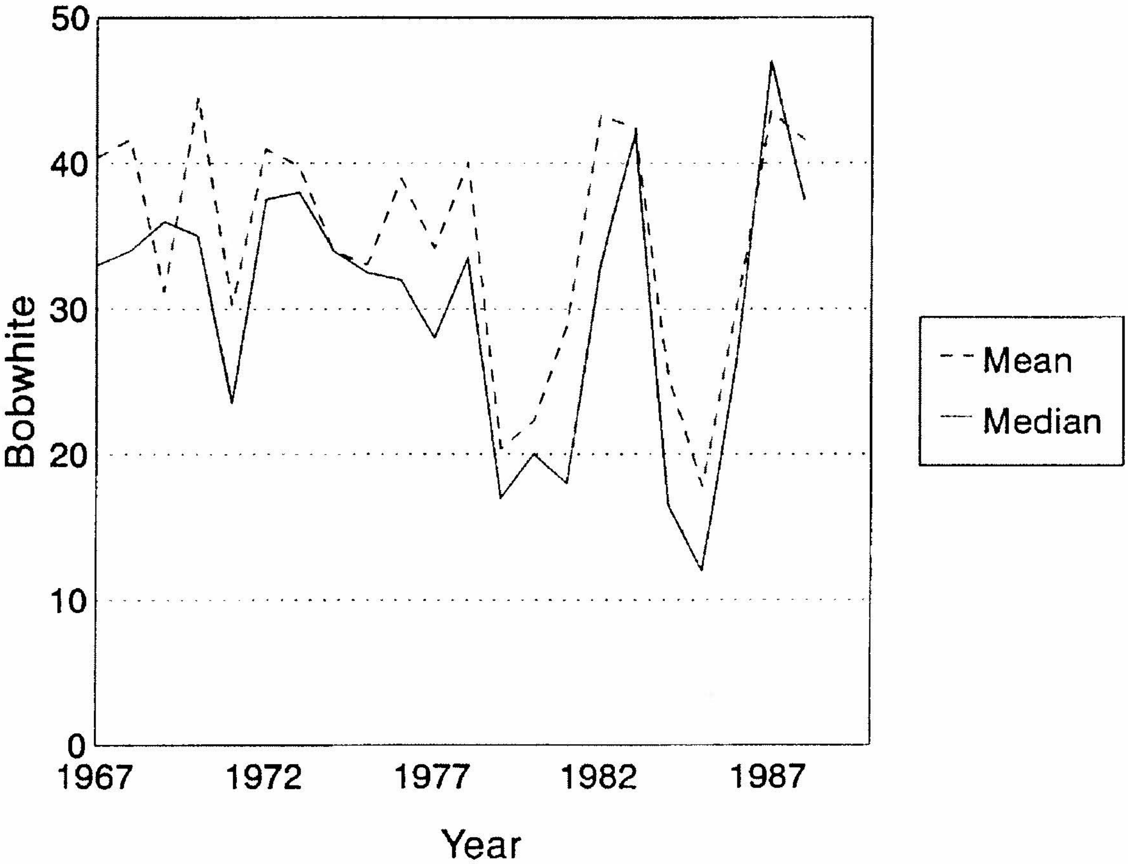

Fig. 2. Numbers of northern bobwhite observed on Breeding Bird Survey routes ($n = 29\text{-}36$) in Kansas, 1967-88.

high-density. Annual BBS estimates of bobwhite abundance revealed no long-term change ($P > 0.1$; Church et al. 1993) since 1967 (Fig. 2). The mean number of bobwhite recorded on BBS routes was 43.3 (SE = 6.6, median = 33, range = 123). In 1982, RMCS data were correlated with the number of individuals ($r_s = 0.78$, $P < 0.0001$) and the number of stops where bobwhite were observed ($r_s = 0.77$, $P < 0.0001$) on 32 BBS routes in 29 counties. This supports the use of both data sets as appropriate measures of bobwhite abundance for comparisons with land-use data.

Land-Use Patterns

In general, the amount of farmland in Kansas has remained stable over the last 50 years. In 1982, 20.1 million ha of rural land consisted of 11.8 million ha of cropland, 6.8 million ha of rangeland, 0.9 million ha of pastureland, 0.3 million ha of woodland, and 0.3 million ha of other minor land cover uses (USDA, SCS and ISUSL 1989). About 51% of rural land and 65% of cropland were classified as prime farmland. Fourteen percent of cropland was irrigated. Sixty-six percent of cropland was used to produce wheat, and the remaining 34% produced sorghum, hay, soybeans, and corn (Fig. 3) (USDC 1984).

Land area used for crop production fluctuates annually because of federal commodity control programs. Techniques for producing crops have been modified by technological advances in conservation tillage for soil erosion control. The area treated with herbicides more than doubled from 1974 to 1987, whereas the use of insecticides has remained relatively constant (Fig. 4). The chemical composition of pesticides has changed dramatically during this period. Beginning in 1986 the Conservation Reserve Program removed about 1.2 million ha of cropland from production for 10 years.

Eight NRI variables (5 positive and 3 negative) were different ($P < 0.05$) between counties where bobwhite were present as opposed to absent (Table 2). Likewise, MRPP identified 14 Census of Agriculture variables (8 positive and 6 negative) that were associated ($P < 0.05$) with the presence or absence of bobwhite.

There were 16 NRI variables (10 positive and 6 negative) that differed ($P \leq 0.05$) between low- and high-density counties (Table 3). Seven NRI vari-

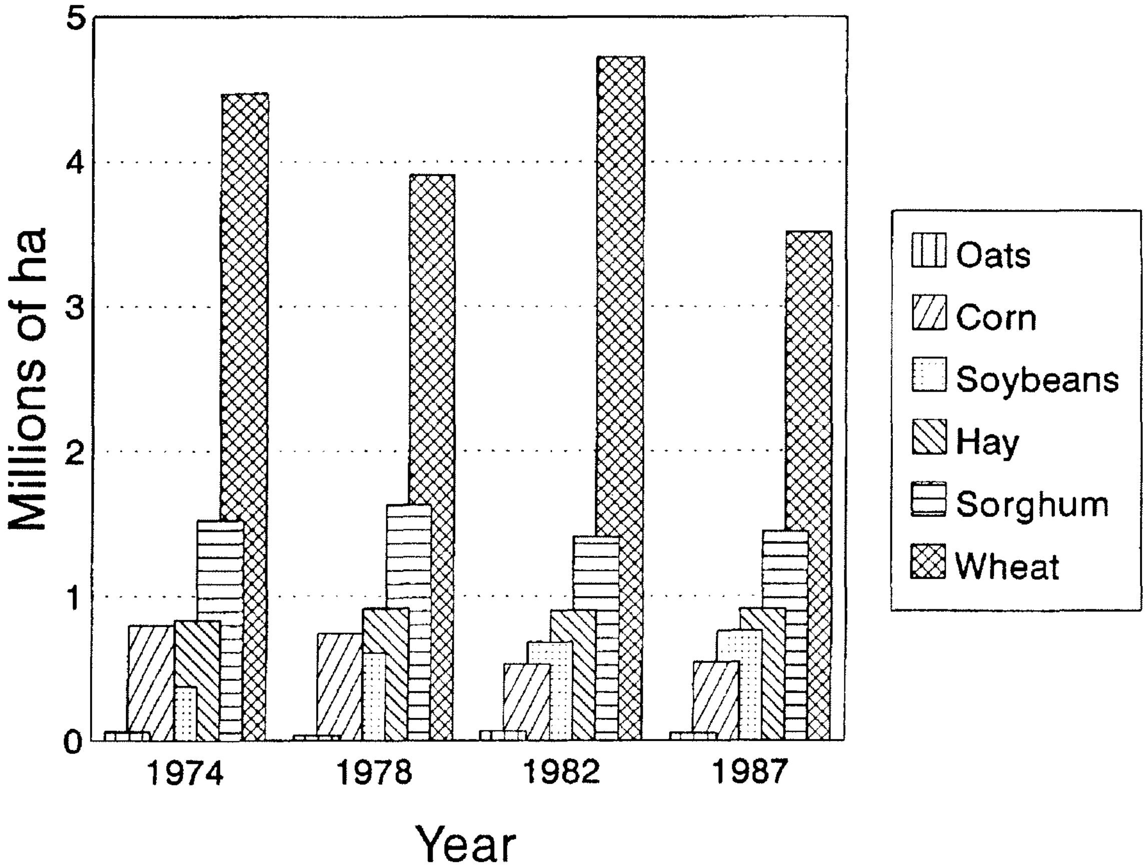

Fig. 3. Major crops produced in Kansas during the last 4 Censuses of Agriculture (USDC 1976, 1980. 1984, 1989).

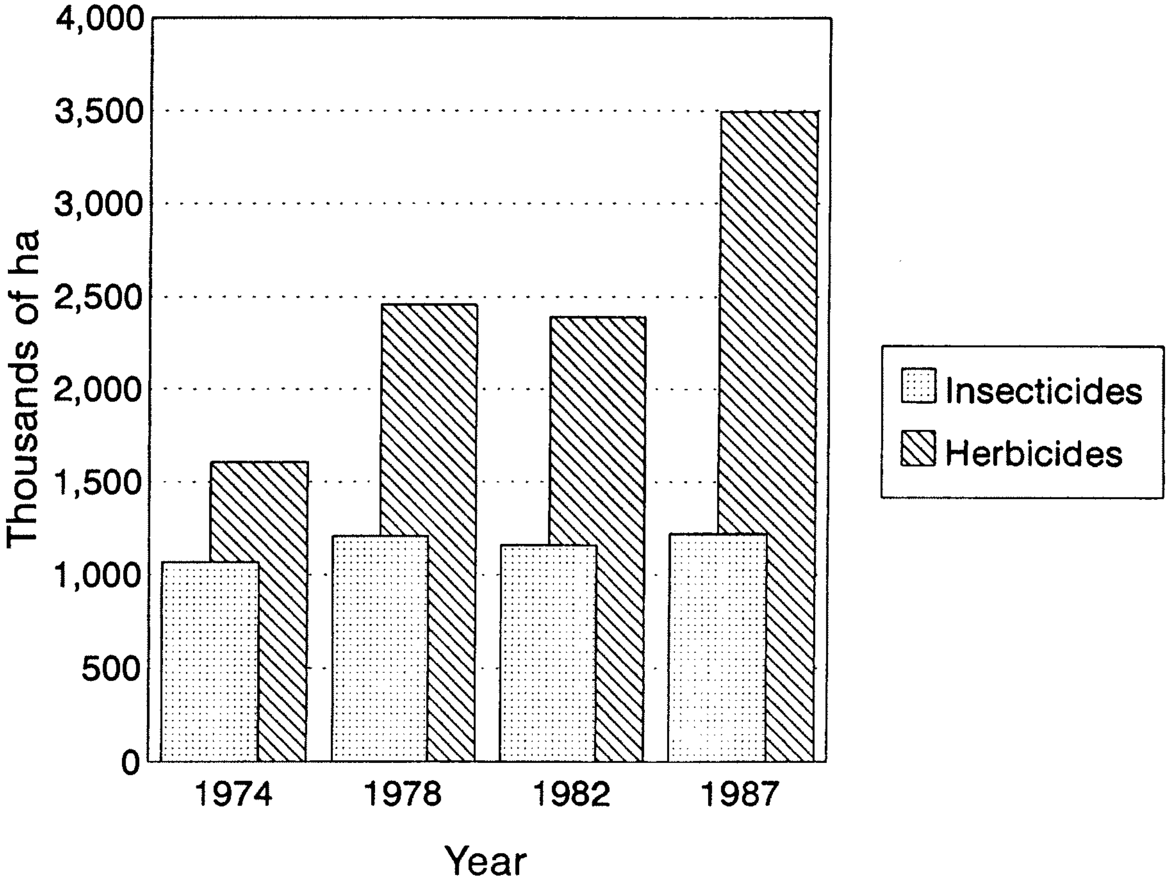

Fig. 4. Kansas agricultural lands treated with herbicides and insecticides during the last 4 Censuses of Agriculture (USDC 1976, 1980, 1984, 1989).

ables were common to both presence/absence and low/high tests. Likewise, 14 Census of Agriculture variables (9 positive and 5 negative) differed ($P <$ 0.05) in low-density, opposed to high-density, counties. Twelve variables were common to both distribution and abundance tests.

Bobwhite abundance was correlated ($P < 0.05$) with 19 NRI variables for the counties where bobwhite were present (Table 4). The rainfall factor displayed the strongest positive correlation and the erodibility index for wind the strongest negative relationship. Spearman's rank correlations were generally supportive of the results of the MRPP abundance tests.

Spearman's rank correlations identified 13 variables associated with bobwhite abundance and Census of Agriculture data (Table 5). The proportion of woodland represented the strongest and most consistent relationship. The proportion of cropland diverted out of production was strongly negatively correlated with bobwhite abundance in 1978 and 1982. However, in 1987 the amount of diverted acres was the greatest among the years examined, and no relationship was identified.

Predictive Models and Trends

The LAD regression analysis indicated that 4 NRI variables best explained northern bobwhite (NBW) abundance (Agreement = 0.48, $P = 0.0001$, $n = 36$). The equation was:

NBW = -0.54 + 52.3 Ponds + 68 Woodland + 21.6 Soybean - 174 Oats + 0.004 Distance to Cropland.

When Census of Agriculture variables were subjected to LAD regression analysis, the best fit came with 3 variables (Agreement = 0.46, $P <$ 0.00001, $n = 80$) giving the equation:

NBW = 1 + 78 Woodland + 98.9 Native hay - 33.3 Hay (except alfalfa).

When the temporal trends of bobwhite abundance (1967-88) were evaluated against agricultural land-use trends (1974-87), no relationship ($P > 0.05$) was observed. Neither the slope of bobwhite trends nor the slope of agricultural land-use trends was different from 0.

Table 2. Multiple Response Permutation Procedure results of Rural Mail Carrier Survey bobwhite distribution with county level National Resources Inventory data for counties where bobwhite were present (n = 36) or absent (n = 11) and Census of Agriculture data for counties where bobwhite were present (n = 90) or absent (n = 15).

National Resources Inventory	*P*	Census of Agriculture	*P*
% LCC1[a]	0.0831	% diverted crops	0.0004
% LCC2	0.2007	% cover crops	0.0828
% LCC3	0.2656	% herbicides	0.1408
% LCC4	0.3156	% insecticides	0.0392
% prime farmland soils	0.0001	% sorghum	0.7448
Erodibility index (water)	0.0002	% oats	0.0018
Erodibility index (wind)[b]	0.0306	Hogs/ha	0.0014
% grazed	0.1178	Cows/ha	0.0011
% cropland	0.0154	% farmland	0.2916
% soybeans	0.0783	% soybeans	0.0100
% wheat	0.1015	% wheat	0.0072
% pasture	0.1532	% past/range fertilized	0.0368
% woodland	0.0107	% woodland	0.0015
% meadow	0.0001	% hay	0.0001
% small water bodies	0.0032	% alfalfa	0.0105
Mean distance to cropland	0.8724	% hay (except alfalfa)	0.0002
Mean distance to grassland	0.0002	% wild hay	0.0198
Mean distance to water	0.0750	Average farm size	0.0001

[a]LCC = Land Capability Class.

[b]EI wind was only calculated for n = 23 counties where bobwhite were present and n = 11 counties where bobwhite were absent.

Table 3. Multiple Response Permutation Procedure results of 1982 Rural Mail Carrier Survey data for bobwhite abundance with county level National Resources Inventory (NRI) and Census of Agriculture data for counties with high and low abundance. High abundance was defined as ≥1.425 bobwhite/161 km and low abundance was <1.425. NRI had 18 counties with high abundance and 18 with low, whereas Census of Agriculture had 58 counties with high abundance and 32 with low.

National Resources Inventory	*P*	Census of Agriculture	*P*
% LCC1[a]	0.4971	% diverted crops	0.0001
% LCC2	0.0424	% cover crops	0.0765
% LCC3	0.0108	% herbicides	0.0235
% LCC4	0.0480	% insecticides	0.0288
% prime farmland soils	0.0315	% sorghum	0.0782
Erodibility index (water)	0.0003	% oats	0.0001
Erodibility index (wind)[b]	0.4128	Hogs/ha	0.0004
% grazed	0.0522	Cows/ha	0.0026
% cropland	0.0037	% farmland	0.0014
% soybeans	0.0030	% soybeans	0.0001
% wheat	0.0239	% wheat	0.0001
% pasture	0.0246	% past/range fertilized	0.1198
% woodland	0.0001	% woodland	0.0001
% meadow	0.0001	% hay	0.0001
% small water bodies	0.0003	% alfalfa	0.3470
Mean distance to cropland	0.0004	% hay (except alfalfa)	0.0001
Mean distance to grassland	0.0130	% wild hay	0.0001
Mean distance to water	0.0023	Average farm size	0.0001

[a]LCC = Land Capability Class.

[b]EI wind was calculated only for n = 23 counties.

Table 4. Spearman's rank correlation coefficients and probabilities of 1982 Rural Mail Carrier Survey data for bobwhite abundance with county level National Resources Inventory data for counties where bobwhite were present (n = 36). Land-use variables were calculated as percent of the land in the county, whereas soil variables were weighted averages.

Variable	r_s	$P<$	Variable	r_s	$P<$
Rainfall factor	0.806	0.0001	Distance to cropland	0.543	0.0006
EI (wind)[a]	−0.760	0.0001	% cropland	−0.524	0.0010
% woodland	0.739	0.0001	Distance to grassland	−0.426	0.0096
% small water bodies	0.701	0.0001	% LCC4[b]	−0.407	0.0136
T factor	−0.696	0.0001	% wheat	−0.404	0.0146
% pasture	0.633	0.0001	% LCC3	0.388	0.0193
EI (water)	0.618	0.0001	% LCC5	0.356	0.0333
Soil erodibility factor	0.600	0.0001	% grazed	0.356	0.0333
% meadow	0.597	0.0001	Length of slope	−0.201	0.0574
% soybeans	0.560	0.0004	LS factor	0.185	0.0805
Distance to water	−0.547	0.0006	Percent of slope	0.181	0.0885

[a]EI wind was calculated only for n = 23 counties.
[b]LCC = Land Capability Class.

Table 5. Spearman's rank correlation coefficients of Rural Mail Carrier Survey (RMCS) and Breeding Bird Survey (BBS) data for bobwhite abundance with Census of Agriculture data for counties where bobwhite were present. Probability values are in ( ) below correlation coefficients. Land-use variables were calculated as percent of the land in the county (e.g., percent of land treated with herbicides).

	RMCS	BBS			
Variable	1982 (n=90)	1974 (n=30)	1978 (n=30)	1982 (n=30)	1987 (n=26)
% woodland	0.759	0.487	0.531	0.716	0.700
	(0.000)	(0.006)	(0.002)	(0.000)	(0.000)
% diverted crops	−0.705		−0.454	−0.642	−0.020
("set aside")	(0.000)		(0.012)	(0.000)	(0.923)
% hay (all)	0.668	0.143	0.436	0.474	0.464
	(0.000)	(0.452)	(0.016)	(0.008)	(0.017)
% wheat	−0.585	−0.105	−0.072	−0.499	−0.631
	(0.000)	(0.579)	(0.070)	(0.005)	(0.001)
% soybeans	0.558	0.375	0.560	0.468	0.565
	(0.000)	(0.041)	(0.001)	(0.009)	(0.003)
Average farm size	−0.506	−0.233	−0.253	−0.306	−0.416
	(0.000)	(0.215)	(0.177)	(0.100)	(0.035)
% oats	0.490	0.129	0.443	0.504	0.328
	(0.000)	(0.496)	(0.014)	(0.004)	(0.101)
Hogs/ha	0.467	0.200	0.073	0.459	0.161
	(0.000)	(0.290)	(0.702)	(0.011)	(0.433)
% farmland	−0.456	−0.297	−0.344	−0.630	−0.337
	(0.000)	(0.112)	(0.058)	(0.000)	(0.092)
% nematicides[a]	−0.388	0.530	0.249	−0.751	0.296
	(0.000)	(0.003)	(0.185)	(0.000)	(0.142)
% cover crop	0.230	0.281	0.011	0.125	0.224
	(0.029)	(0.132)	(0.954)	(0.509)	(0.272)
% pasture and	−0.228	0.388	0.539	−0.102	0.638
range fertilized	(0.030)	(0.034)	(0.002)	(0.590)	(0.000)
% herbicides	0.195	0.419	−0.072	0.160	0.187
	(0.065)	(0.021)	(0.703)	(0.399)	(0.361)

[a]Number of counties reporting hectares treated with nematicides was 50, 8, 22, 14, and 17 for the 5 columns, respectively.

Whereas the best regression models did not include the erodibility indexes, they are important in targeting USDA programs. The strong positive correlation of bobwhite with the erodibility index (EI water; Table 4) was not found for populations range-wide when tested in 530 counties with BBS data in 1982. However, when bobwhite from all Kansas BBS routes during the years 1970-88 were tested against the EI (water), the correlation was significant ($0.00005 < P < 0.029$) for each year. The EI is a function of the relatively stable natural factors of climate, soil, and length and percent of slope, which will be relatively constant over time, unlike the agricultural land-use variables that can fluctuate annually.

The physiographic and climatic gradient across Kansas from east to west could confound interpretations of our results. However, we tried to minimize this concern by evaluating both abundance within the occupied range and distribution. Population density may be a misleading indicator of habitat quality, especially with high resolution studies (Van Horne 1983). We found that rank ordering of counties by bobwhite abundance was consistent over time and that bobwhite abundance in the extreme low and high years of 1985 and 1987 were highly correlated ($r_s = 0.77$, $P < 0.00001$). Source and sink bobwhite populations were not distinguishable at the county level.

DISCUSSION

The bobwhite is an edge-associated species whose abundance is generally increased by greater habitat diversity. The EI correlations and correlations with spatial variables (distance to crop, grass, and water in Tables 2-4) confirm this relationship. High values for the EI (water) imply highly dissected landscapes characterized by short, steep slopes, steep waterways, more rainfall, and high topographic relief--hence high habitat heterogeneity. Conversely, high values for the EI (wind) imply gently rolling to flat plains, gentle slopes, less rainfall, wide open spaces--hence high habitat homogeneity. Bobwhite were more abundant in counties where mean distances to grassland and small waterbodies were low. Bobwhite were less abundant in counties where mean distance to cropland was low.

Bobwhite abundance was positively correlated with amount of pasture and hayfields or meadows. Hayfields and pasture in southern Illinois offered some nesting cover, depending upon vegetational composition and structure (Roseberry et al. 1979). These results are also consistent with the findings of Exum et al. (1982) except for correlations with soybeans. Exum et al. found that although soybeans were a preferred food of bobwhite on the Ames Plantation in Tennessee, population size was negatively correlated with area maintained in soybeans. Large expanses of soybeans replaced large idle fields and permanent pastures on the Ames Plantation, perhaps creating shortages of necessary winter cover (Exum et al. 1982). In contrast, the expansion of soybeans in Kansas replaced other cropland (primarily corn) rather than converting good bobwhite cover to less desirable cropland. Therefore, if crop rotations are shifted from other crops to include soybeans without the concomitant loss of important habitat types, then bobwhite populations might benefit.

Avian habitat use is dynamic (O'Connor 1986), may be nonlinear (Meents et al. 1983), and varies with population demographics (Van Horne 1983, Maurer 1986) as well as with the scale with which we classify habitats (Wiens et al. 1987). Bobwhite were correlated consistently with some variables and inconsistently with others. The inconsistent variables might be less important, or the scale that they operate in might be different from the scale bobwhite population processes operate in. Reconciling the scale of agricultural programs and technologies with bobwhite population processes is only likely to occur in a hierarchical framework. However, EI and proportions in woodlands and soybeans are important variables because of their consistent correlations with bobwhite populations over time.

The fact that woodlands occur and soybeans are grown more in eastern Kansas where rainfall is greater and bobwhite are abundant does not necessarily imply a causal relationship. However, environmental conditions where these land uses occur also provide conditions suitable to higher bobwhite abundance. Managers must recognize bobwhite as a successional species and provide appropriate patterns of plant seral stages (Ellis et al. 1969). Subtle land-use changes can cause substantial changes in bobwhite carrying capacity (Roseberry et al. 1979). Detecting successional patterns was not possible with our coarse-grained data, but patterns of major land-use characteristics were detectable and important in describing bobwhite abundance.

The USDA conservation programs are targeted to highly erodible lands based on the EI. In the eastern 2/3 of Kansas where bobwhite are abundant, those programs will also target areas where bobwhite are abundant. However, in the western

1/3 of Kansas, those programs will target counties where bobwhite are rare or absent since the EI (wind) will be the predominant index used to target highly erodible lands. Conservation programs will enhance bobwhite habitat through planned agricultural practices when requirements of this game bird are kept in mind. Traditional soil conservation practices such as grass-ridged terraces, field windbreaks, contour stripcropping, field border strips, and proper grazing are still good recommendations. Negative correlations with distances to grass cover and to water show the importance of habitat diversity and interspersion. Increasing size of farms and fields may result in the loss of brushy fencerows and odd areas of habitat which will be difficult to mitigate, even with judicious planning.

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