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Projecting the bird community response resulting from the adoption of shelterbelt agroforestry practices in Eastern Nebraska

R. A. Pierce II[1,*], D. T. Farrand[2] and W. B. Kurtz[3]
[1] *Department of Fisheries and Wildlife Sciences, The School of Natural Resources, University of Missouri, 302 ABNR Bldg., Columbia, MO 65211, USA;* [2] *Food and Agricultural Policy Research Institute, 101 S. Fifth St., Columbia, MO 65201, USA;* [3] *Department of Forestry, The School of Natural Resources, 124 ABNR Bldg., Columbia, MO 65211, USA (*Author for correspondence; E-mail: Piercer@missouri.edu)*

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Abstract

Evolving agricultural policies have influenced management practices within agroecosystems, impacting available habitats for many species of wildlife. Enhancing wildlife habitat has become an explicit objective of existing agricultural policy. Thus, there is renewed focus on field borders and the use of shelterbelt agroforestry systems to achieve conservation goals in the Midwest. Two Representative Farms – a 283-ha dryland and 510-ha irrigated farm were created in Saunders County, Nebraska. The Habitat Analysis and Modeling System (HAMS) was used to describe the composition and spatial pattern of the existing farms and surrounding landscape, as well as for the landscapes surrounding selected Breeding Bird Survey (BBS) routes. Simulated land use changes resulting from the implementation of two shelterbelt scenarios, Agricultural and Wildlife, were incorporated on each Representative Farm and surrounding landscape. Landscape variables which influence breeding bird species richness and community composition as determined from BBS routes were measured on simulated farm landscapes. A more heterogeneous landscape results from implementing either scenario. The percent total woods was a significant determinant of bird species richness on the BBS routes and was important in influencing bird communities at the farm- and landscape-level. Other landscape metrics which influenced the bird community composition on BBS routes were woody edge percentages and edge density values. Policies promoting shelterbelts create edge habitats which ultimately favor birds within the Forest-edge/generalist guild while bird species in need of conservation such as grassland-field species would potentially be negatively affected.

Introduction

Wildlife conservation within agricultural landscapes is often limited by conflicts between economic and conservation objectives and by the voluntary nature of agriculture programs. A reduction of agricultural landscape diversity continues to be a trend in many areas of the country involved in growing feed grains and grain for human consumption. This reduction of diversity implies an increase in the percentage of land managed for row crops, a reduction of perennial woody cover and grassland acreage and a reduction of wildlife habitat quality associated with agricultural landscapes. Examples include the fencerow to fencerow production of crops, which eliminates hedgerows, windbreaks, grassy field borders and other types of habitat necessary for many avian species associated with agricultural land (Best et al., 1995).

Emerging agricultural and conservation policies have funded voluntary programs designed to develop and enhance wildlife habitats on private lands. The implementation of these new conservation provisions have the potential to enhance agricultural landscape diversity, improve wildlife habitats, and provide incentives which allow agricultural producers to manage land as a system to maximize profitability and resource sustainability.

Lassoie and Buck (1991) indicated that agroforestry systems could serve as a conceptual model for new approaches to land-use management and serve as a design for reuniting the fields of agriculture and forestry. According to Garrett et al. (1994), properly designed agroforestry practices have the potential to yield many benefits, including increased landscape diversification within intensively cropped agricultural systems through the establishment of windbreaks, shelterbelts and woody hedgerows.

Johnson and Beck (1988) confirmed the importance of shelterbelts for a variety of bird species, while Schroeder et al. (1992) identified such characteristics as total area, edge configuration, plant diversity and structural complexity of vegetation as key indicators of habitat quality. Little research has been conducted to evaluate the wildlife habitat which results from the adoption of agricultural policies promoting agroforestry land management systems. While decisions on crop production and managing land cover are made by individual landowners, their impacts are seen cumulatively, as a change in spatial pattern on the landscape. As Best et al. (1995) has noted, few studies have investigated landscape-level patterns of agricultural practices and evaluated the spatial arrangement of crop lands and non-crop lands on bird species composition and abundance.

The appraisal of wildlife habitats within agroecosystems, either at the farm- or landscape-level, which results from the implementation of a particular agricultural policy influencing land use, requires the ability to accurately forecast the consequences of these human-induced environmental changes. The ability to inventory, quantify, and evaluate habitat at various spatial scales is becoming more essential for effective wildlife management as many of these decisions are increasingly being made at the landscape-level.

The shift in focus from smaller to larger scales is concurrent with technological advances in remote sensing, geographical information systems (GIS), and methods for quantifying spatial attributes of landscapes. Land use and cover can be inventoried and classified over large geographic areas using satellite imagery or through the use of digital orthophotoquads. Landscape composition and pattern can be described by a variety of metrics, including spatial heterogeneity, fragmentation, edge characteristics and connectivity. Each of these metrics, as well as such landscape characteristics as patch size, edge length, and spatial arrangement of cover types, can be significantly altered as agroforestry practices are integrated into the agroecosystem. An understanding of how policy adoption can modify the landscape pattern, and therefore the availability of habitats within agroecosystems, may serve to minimize potential negative impacts and enhance habitats for desired wildlife species.

Purpose and objectives

Policies which promote the integration of shelterbelts within an agroecosystem have the potential to influence both vertical structure and the spatial pattern of a landscape, both influencing the breeding bird community. Freemark (1995) indicated that bird community patterns at a given spatial scale (i.e., at the farm-level) are related to the landscape context at a larger scale.

Bird populations and communities change as habitats are altered. Vertical vegetative structure created by shrubs and trees, the degree of heterogeneity created by field edges within the landscape, the size of fields and the degree of permanent vegetation all serve to influence the availability and suitability of nesting and foraging habitats for birds. Landscape structure and the establishment and management of non-crop areas are also influenced by agricultural policies. Few studies have investigated the patterns of agricultural practices at the landscape-level, such as the distribution and pattern of croplands and noncroplands and their influence on bird species richness, community distribution and composition.

The overall purpose of this study was to develop a methodology capable of evaluating the changes in wildlife habitat that occur as a result of the adoption of conservation practices at the farm-level as influenced by agricultural policy. The more specific objective of this study was to project the change which may occur within the avian community as a result of proposed agricultural policies utilizing shelterbelts at the farm- and landscape-level. This investigation was intended to provide insights into the development of a decision-making and modeling system linking econometric and environmental models (Cassidy, 1998) with landscape-level habitat analysis and provide implications for future research needs in farm-level policy analysis.

With the advent of GIS technology, it is possible to simulate placement of a proposed management practice and modify cover type changes (which may have resulted from the implementation of an agricultural policy) on a landscape map. It then becomes possible to examine the effect of a proposed management modification on selected aspects of landscape pattern and evaluate the habitat suitability of the simulated land use for selected wildlife species or communities (Roseberry and Hao, 1996).

Materials and methods

Description of the study area

Nebraska lies within the Great Plains physiographic region, and Saunders County, located in east-central Nebraska, south and west of the Platte River, is in USDA Major Land Resource Area 106 which is characterized by loess uplands and till plains. The agroecosystem of east-central Nebraska is characterized by a rather simple land-use matrix; more than 90% of the region is in an agricultural use, primarily devoted to dryland or irrigated row crop production. Principle crops include corn, soybeans, grain sorghum, alfalfa, and oats. Wooded sections are generally characterized by narrow riparian areas along streams and rivers or shelterbelts around farmsteads. Irrigation is being increasingly practiced in areas where water supplies are available (K. Glewen, Univ of NE, pers. comm.).

Characteristics of the representative farms

The use of irrigation for the production of row crops is an important factor which can be used to describe farms in this portion of Nebraska. Topography prevents widespread use of irrigation equipment and the use of such equipment often determines field sizes and management practices (K. Glewen, Univ of NE, pers. comm.). Thus, we classified the farms in this area as either 'dryland' or 'irrigated'.

The Extension Educator with the Cooperative Extension System in Saunders County selected six farmers to serve on each representative farm (dryland and irrigated) panel. These farmers lived in the same geographical area and operated farms of approximately the same size and composition. Each representative farm panel worked as a team to describe the landscape characteristics of a typical farm in their respective area of the county. From this process it was determined that the acreage and landscape from one of the existing farms was representative of all the other farms in the area. The existing land characteristics of the dryland and irrigated farm were used as our 'baseline' condition.

The dryland representative farm was located in western Saunders County (Figure 1) and was 283 ha in size; with approximately 230 ha of crops, 40 ha of pasture, and 12 ha of woodlands dispersed across the farm. Field windbreaks were not typically present, however, small blocks of trees and shrubs were common along fencerows, scattered along property lines and throughout drainage areas and stream corridors.

The irrigated representative farm was located in eastern Saunders County (Figure 1) and was comprised of 502 ha of cropland: 251 ha of corn and 251 ha of soybeans. Over 50% of the crops were irrigated and field sizes were significantly larger than the dryland farm to accommodate irrigation systems. The landscape was practically void of trees or shrubs; fencerows and field borders were uncommon. Most of the trees in the landscape were located around the farmstead.

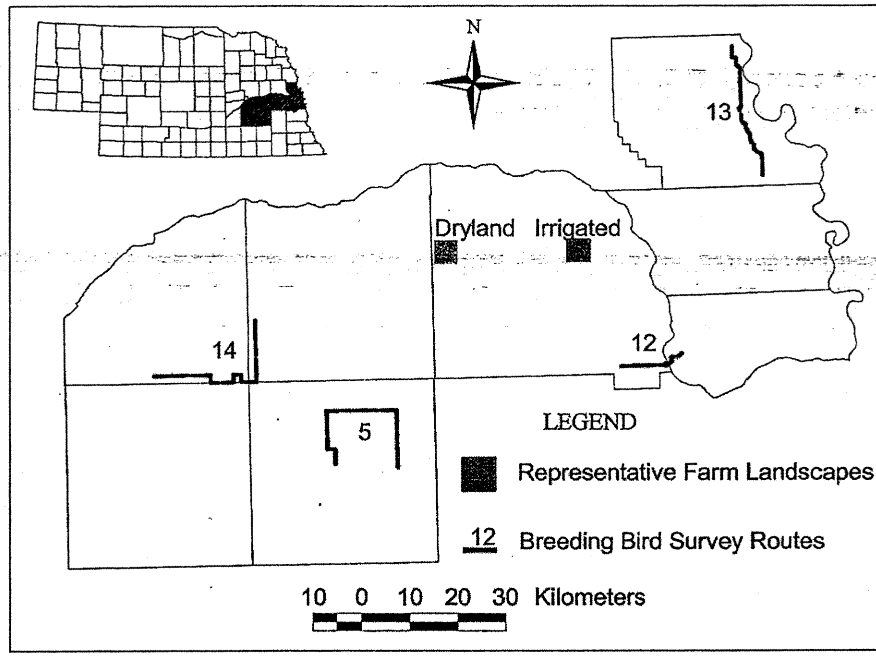

Figure 1. Breeding Bird Survey (BBS) routes in east-central Nebraska and their locations relative to the landscapes surrounding each representative farm.

Development of the representative farm scenarios

Three scenarios were developed on which wildlife habitat assessments were conducted: (1) the Baseline scenario, which reflected the characteristics of the existing landscape and did not include the use of shelterbelts; (2) the Agricultural scenario, in which a single-row shelterbelt (commonly referred to as a field windbreak) composed of deciduous trees was strategically utilized for agronomic benefits and for the reduction of wind erosion (Brandle et al., 1992); (3) the Wildlife scenario, a multi-row shelterbelt design which consisted of a coniferous/deciduous tree/shrub mix for enhanced wildlife habitat (Johnson and Beck, 1988). Johnson et al. (1991) provides a list of trees and shrubs together with their value to wildlife which could be planted in Nebraska shelterbelts. A Geographic Information System was used to describe the existing field conditions as well as to simulate the strategic placement of the Agricultural and Wildlife shelterbelt scenarios. A description of the two shelterbelt scenarios used for policy analysis follows.

Agricultural scenario

- reflects an optimal shelterbelt practice for the objective of increasing net farm income through increased crop yields as a result of microclimate modification.
- utilized deciduous trees in a single, 5.3 m width row configuration with 4 m spacing between the trees; at maturity, the trees were expected to reach a height of 10 m; the useful lifespan of the shelterbelt (field windbreak) was assumed to be 50 years.

Exterior and interior field windbreaks were placed strategically onto crop fields to enhance yields and reduce wind erosion following a process described by Cassidy (1998). The placement of field windbreaks on the landscape followed the same pattern used at the farm-level, with the assumption that each farmer incorporated field windbreaks on each cropfield, as the condition warranted.

Wildlife scenario

- reflects a multi-row shelterbelt practice with greater plant and structural diversity for enhanced wildlife benefits; increasing crop yields was a secondary consideration.
- utilized five rows of trees and shrubs; at maturity, the trees were expected to reach a height of 10 m; the useful life of the shelterbelt was assumed to be 50 years.
- the total width of the shelterbelt was 42.6 m, comprised of the following (beginning from the windward side):
  - Row 1: Short shrubs planted at a spacing of 2 m; provides nesting sites, food and cover in the midstory and near ground level;
  - Row 2: One deciduous tree at a 3.3 m spacing alternating with a coniferous tree at a 2.6 m spacing; deciduous trees provide nesting and foraging sites, food, canopy and habitat structure; conifers provide excellent winter cover, food and nesting sites;
  - Row 3: Same as Row #2;
  - Row 4: Tall deciduous shrubs planted at a 2.6 m spacing; provides nesting sites, food and cover both in the midstory and near ground level;
  - Row 5: Same as Row #1.

Exterior shelterbelts were placed on the southern and western field borders to offer protection from the prevaling winds. No multi-row shelterbelts were incorporated within the interior of crop fields on either the dryland or irrigated farm or surrounding landscapes.

Habitat analysis methods

Methods of analysis to describe landscapes

Figure 1 depicts the location of each representative farm and surrounding landscape as well as the location of the Breeding Bird Survey (BBS) routes. Landscape characteristics within a 23.3 square kilometer area around each representative farm were digitized from full resolution (1 m^2) digital orthophotoquads (DOQ, Spring 1993) using ARC/INFO. This area allowed for the accurate delineation of land-use classes as well as for the determination of emerging land-use patterns which may result from the adoption of a particular policy scenario. Similarly, a 0.4 kilometer radius around each BBS route was digitized. This area reflected the maximum area in which an observer can reliably detect birds by sight or sound (Bystrak, 1981).

Land cover class designations were assigned using visual interpretations of high altitude color infrared (CIR) photography (scale 1:12,000, 1993) and the DOQ's. In addition, landscape maps were verified by ground-truthing procedures. These tools allowed us to identify six broad land cover classifications, including: (1) woodlots, including all contiguous blocks of woods with canopy cover > 50% and shelterbelts > 1 row of trees; (2) individual trees, including all solitary trees, single rows of trees, and scattered groups of trees with < 50% canopy cover; (3) row crops; (4) grasslands, including all pastures, hayfields, CRP fields, and grassy waterways; (5) water, primarily farm ponds; and (6) farmsteads, roads and urban areas.

Property boundaries for each of the representative farms were digitized as a separate layer in order that individual fields could be subsequently extracted apart from their respective landscapes for farm-level analyses. For farm-level analyses, only those fields contiguous with the homestead (defined as the representative farm core area, RFCA) were assessed.

Bird data obtained from four BBS routes, located in the vicinity of the RFCA's (Figure 1) were utilized for establishing bird habitat relationships at the landscape-level. Surveys of these BBS routes from 1992 to 1994 were used for the present analyses. This provided a consistent relationship with the habitats within each of the landscapes described from the DOQs, which were taken during the Spring of 1993. These routes were divided into five equal sections corresponding with divisions (pages) in the census data. Full DOQ coverage for the four selected routes was unavailable, thus only 16 of the potential 20 pages of data were analyzed.

Vector polygon coverages for each representative farm (2), surrounding landscape (2), and BBS route segments (16) were converted to rasters and subsequently imported into the Habitat Analysis and Modeling System (HAMS) Version 1.0 (Roseberry and Hao, 1996) for analysis of various landscape metrics. The spatial resolution of the rasters was increased to 3 m^2 in accordance with processing limitations of HAMS (J. Roseberry, pers. comm.).

Figures 2 and 3 delineate the composition and spatial arrangement of the existing dryland and irrigated RFCA's (Baseline scenario) as well as each of the alternative landscape images which resulted from the adoption of either the Agricultural or Wildlife scenario. Figure 4 shows the composition and spatial arrangement of the existing landscape image surrounding the irrigated RFCA (Baseline scenario), while Figure 5 depicts the alternative landscape image which resulted from the adoption of the Wildlife scenario. Landscape characteristics for each RFCA and simulated policy scenario were quantified with selected landscape metrics provided by HAMS (Table 1).

Avian guild development

Bird species were classified in terms of response guilds – groups of species that respond similarly to a type of habitat or utilize similar vertical habitat layers for nesting and feeding (Verner, 1984). Birds inhabiting temperate farmland habitats can be classified as Grassland-field, Grassland-edge, Forest-edge and generalist, Forest interior and Aquatic species (Poulsen, 1997). We classified breeding birds found among terrestrial habitats in eastern Nebraska (Johnsgard, 1979; Fitzmaurice, 1995; Poulsen, 1997) into the following guilds based upon their nesting requirements: Grassland-field (GR, nest in open areas); Grassland-edge (GE, require habitats with a limited amount of woody vegetation for nesting or courtship behavior); Forest-edge and generalists (FEG, require habitats and field edges composed of woody vegetation and often are associated with

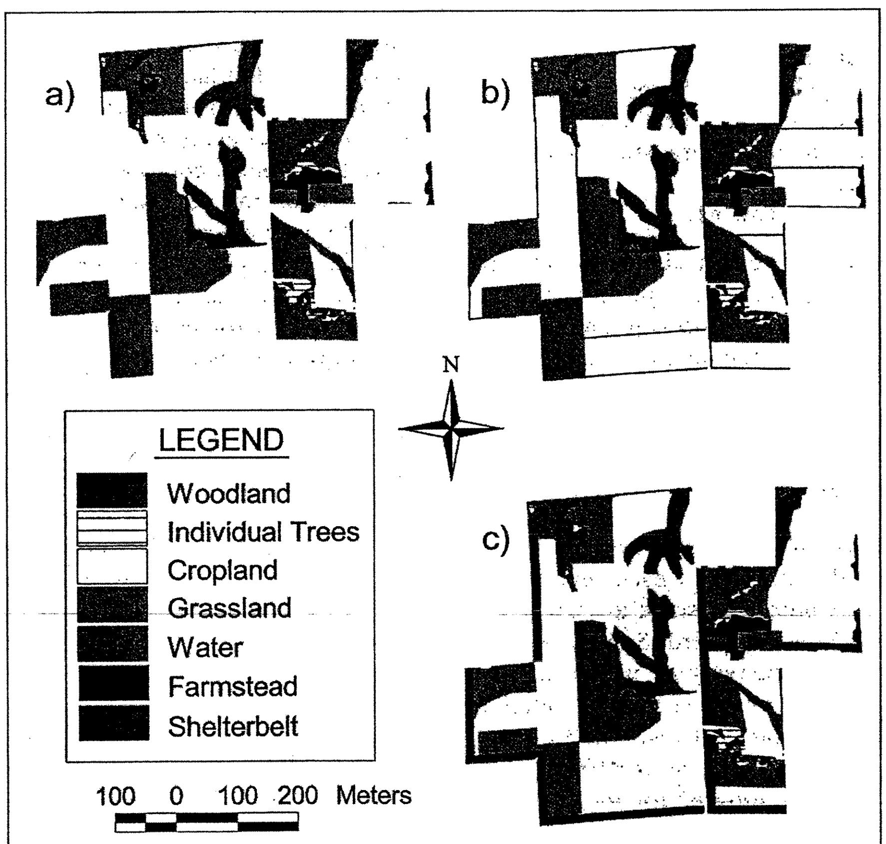

Figure 2. Digital land cover map of the Dryland Representative farm core area in east-central Nebraska, depicting implementation of the (a) Baseline (b) Agricultural and (c) Wildlife shelterbelt scenarios.

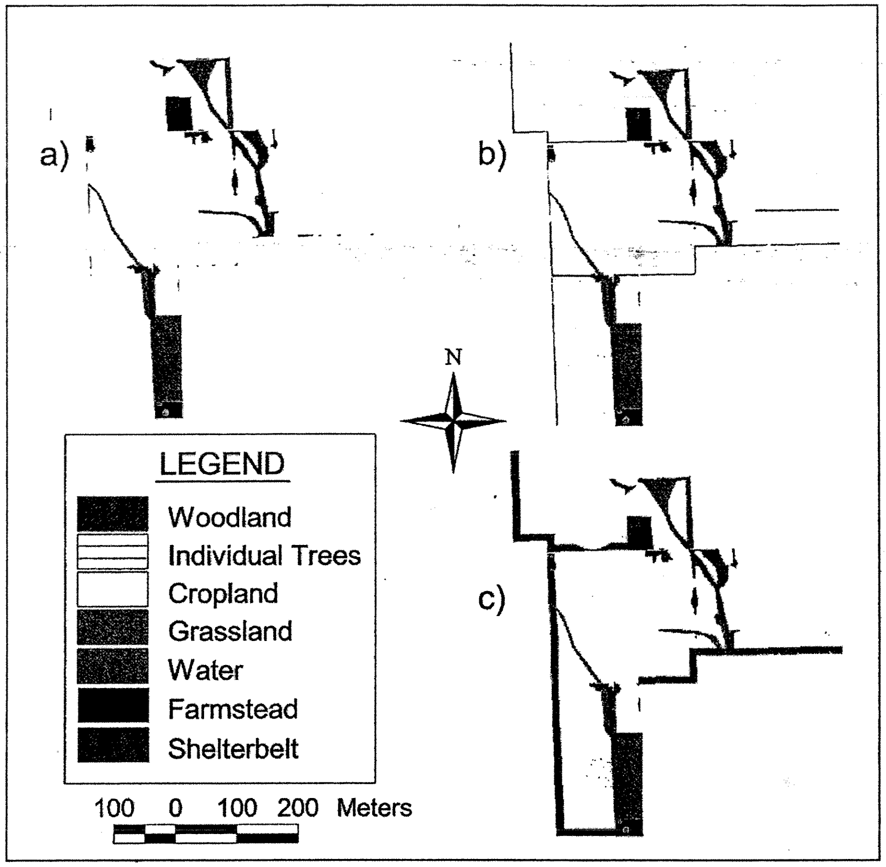

Figure 3. Digital land cover map of the Irrigated Representative farm core area in east-central Nebraska, depicting implementation of the (a) Baseline (b) Agricultural and (c) Wildlife shelterbelt scenarios.

human habitation); and Forest-interior (FI, require larger tracts of wooded land for nesting).

The response guilds and representative species likely to be influenced from the implementation of either the Baseline, Agricultural, or Wildlife scenarios at maturity are listed in Table 2. Bird species listed under the Wildlife scenario include species requiring midstory (short and tall shrubs) habitats which were assumed to be unavailable in single-row field windbreaks at maturity (Agricultural scenario). It was assumed that birds nesting in single-row field windbreaks would also nest in multiple-row shelterbelts (Wildlife scenario). Although birds in the Forest interior guild have been observed in shelterbelts and other woody habitats in eastern Nebraska (Fitzmaurice, 1995; Poulsen, 1997; Poague et al., 2000), we made the assumption that the area of habitat provided by the Agriculture and Wildlife scenarios would likely restrict the availability of nesting sites (e.g., snags and cavities) required by many of these bird species.

The creation of edge habitats, such as those created by the use of shelterbelts, within landscapes dominated by large proportions of row crops can be described as a severe habitat change. Thus, an assumption was made that members of each habitat response guild would respond consistently to habitat alterations created by each of the policy scenarios (Verner, 1984). Also, the total number of species (species richness) and the total number of individuals of all species in a particular guild (relative abundance) were used to predict the guild response to habitat alterations resulting from the implementation of a particular policy.

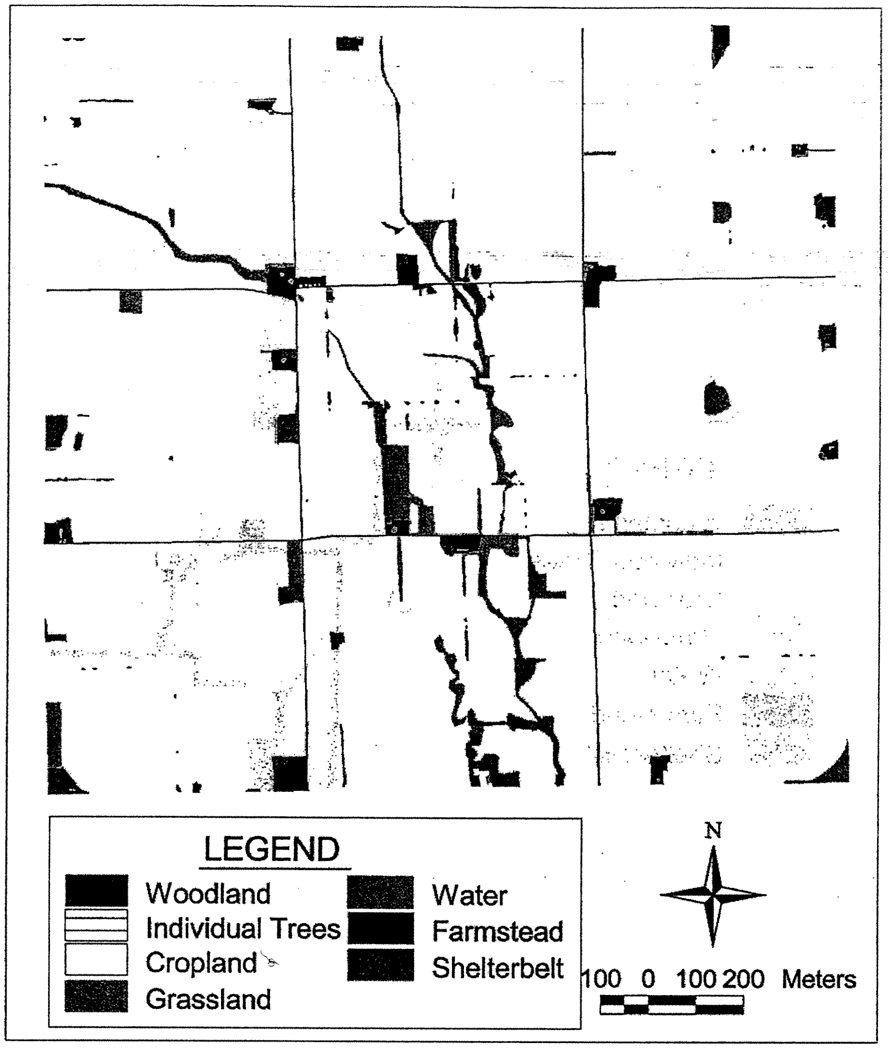

Figure 4. Digital land cover map depicting the landscape of the Baseline scenario surrounding the Irrigated Representative farm core area in east-central Nebraska.

Use of the Breeding Bird Survey

Birds represent a class of vertebrate species for which there is generally good inventory data across the United States. The North American Breeding Bird Survey (BBS), coordinated by the United States Department of Interior, US Geological Survey, was used to characterize avian community structure for the landscapes represented by the RFCA's. According to Bystrak (1981), the BBS is based on 42-kilometer roadside surveys, each containing 50 stops at 0.8-kilometer intervals. A census on each active BBS route is conducted annually on one occasion between mid-May through the first week of July. The finest spatial resolution of the available BBS data was the page-total level (10 stops), while the finest temporal resolution of the data was one year.

Poulsen (1997) examined data from 41 BBS routes in Nebraska during a 10-year period (1981 to 1990) and found there were no significant variations in the number of bird species at the page-total level within routes. Poulsen (1997) also determined that the number of species on each route was not significantly different between years and found that the variation between bird numbers was relatively small among years. Because only

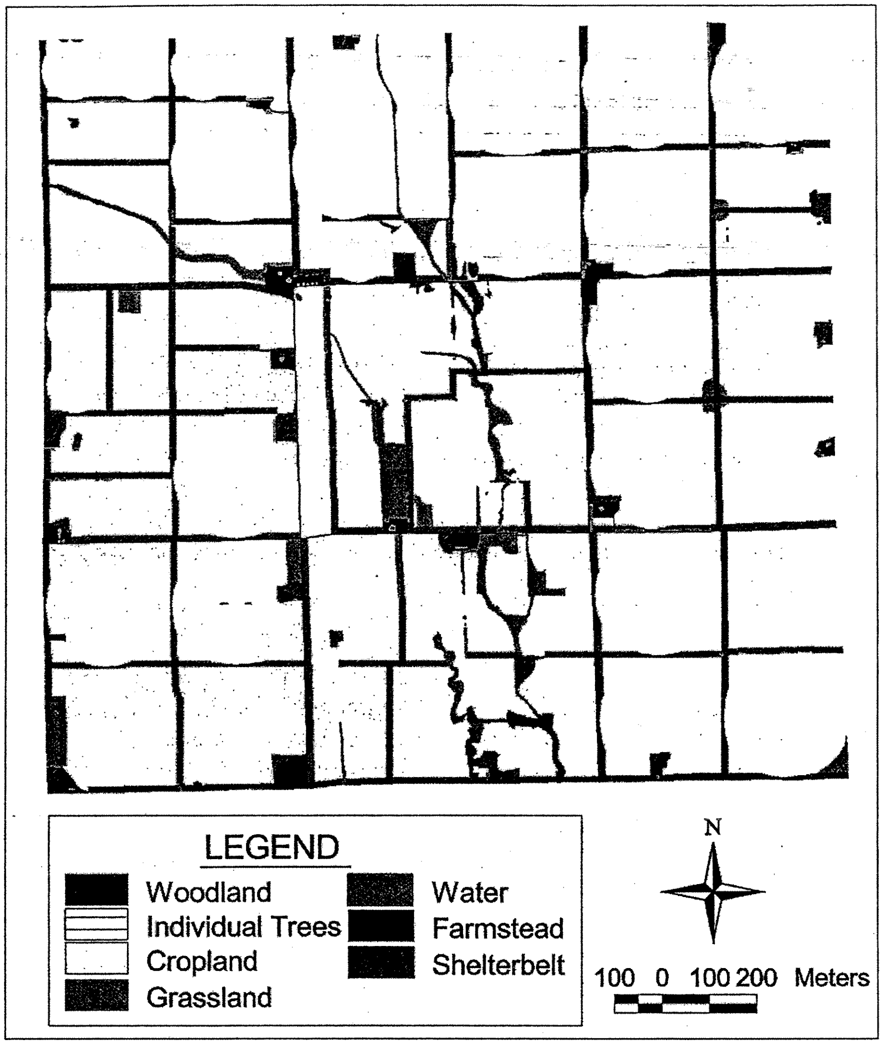

Figure 5. Digital land cover map depicting the implementation of the Wildlife shelterbelt scenario on the Irrigated landscape in east-central Nebraska.

four BBS routes were examined and annual variations were relatively small, bird data were pooled across years to obtain a single value to reduce the potential influence of observer error. For each page of census data, species richness and relative abundance were summarized for each guild and compared to landscape composition for that route segment.

Modeling strategy

Table 3 shows the landscape metrics which were selected from their correlates to serve as independent variables in the analysis of avian habitat relationships on the BBS routes. Regression analysis was used to select those landscape metrics (independent variables) which best predicted bird species richness and relative abundance statistics (dependent variables) on the landscapes surrounding the BBS routes. These landscape metrics were used to serve as potential predictors of the dependent variables.

Stepwise regression was used to determine the 'best' subset of predictors. Statistical Analysis Software (SAS) was used to provide regression analysis and to calculate the Pearson product-moment correlation between all variables to deter-

Table 1. Description of landscape metrics calculated by the Habitat Analysis and Modeling System (HAMS).

HAMS metrics	Description
Proportions	The percentage of the study area occupied by each defined land cover class (e.g., woodlot, row crop, grassland).
Contagion	An index measuring the extent to which classes are aggregated or clumped. Values range from 0 to 1 with landscapes characterized by large, continuous patches tending to have large values and landscapes dissected into many small patches tending to have low values.
Dominance	The degree to which one or a few cover classes dominate the landscape. Values range from 0 to 1 with higher values associated with greater dominance. HAMS uses Shannon's Dominance Index.
Diversity	An index combining two components, richness (the number of land cover classes present) and evenness (their proportionate distribution in the landscape). Values range from 0 to 1 with higher values indicating greater diversity. HAMS uses Simpson's Diversity Index.
Interspersion	The ratio of the total number of connections between pixels of different land cover classes divided by the maximum possible number of connections.
Shared Edge Distance	The total number of adjacencies between pixels belonging to two different land cover classes (computed for all combinations of classes). This metric was used to calculate Total Edge, Edge Density, and Woody Edge Proportion (i.e., the proportion of total edge where one land cover class was woods).

mine which ones were highly correlated ($r^2 \geq 0.90$). The stepwise regression probability criteria of $P = 0.15$ was used in this analysis. Thus, only one independent variable was selected from any group of highly correlated variables for entry into the model (Table 3).

Results

Calculation of landscape metrics

Table 4 provides a description of the dryland and irrigated RFCA and surrounding landscape (Baseline scenario). Field sizes were much larger and more contiguous on the irrigated RFCA than on the dryland RFCA, reflecting a more homogenous landscape. This fact was evidenced by higher Contagion and Dominance values and lower Diversity Index and Interspersion values on the irrigated RFCA relative to the dryland RFCA. The homogeneity of the irrigated RFCA also was reflected in the total edge and edge density metrics. Landscape cover class proportions and metrics of each RFCA were similar to those of their surrounding landscape.

Metrics were also calculated for the landscapes surrounding each of the individual BBS route segments (16). Each route segment averaged 621 ha and were largely dominated by row crops (range 17 to 95 percent, averaging 71 percent). Woody and grassland acreages on each route segment varied, averaging six and 15 percent respectively.

Description of the bird community structure for each of the BBS route segments

Variation in the total species richness and relative abundance of birds between BBS route segments (page-total level) was primarily due to the influence of the Forest-edge/generalist guild. This guild dominated the bird community structure on each segment, making up 83 percent of all individuals and constituting 75 percent of all species. At the page-total level, there was little variation in species richness for the Grassland-field, Grassland-edge and/or Forest-interior guilds. Each of these guilds contained only a few commonly observed species. An average of four birds within the Grassland-field guild were observed on each route segment, constituting 16 percent of the birds species observed. Five percent of the species observed constituted birds within the Grassland-edge guild, with an average of only one species observed per route segment. Birds within the

Table 2. Subset list of bird species, grouped by habitat response guild, which would be expected to inhabit the study area with no shelterbelts, single-row shelterbelts (Agricultural scenario) and multi-row shelterbelts (Wildlife scenario) in east-central Nebraska.

Scenario	Guild	Species
Baseline	Grassland field	Northern Harrier (*Circus cyaneus*)
		Killdeer (*Charadrius vociferus*)
		Upland Sandpiper (*Bartramia longicauda*)
		Horned Lark (*Eremophila alpestris*)
		Bobolink (*Dolichonyx oryzivorus*)
		Eastern Meadowlark (*Sturnella magna*)
		Western Meadowlark (*Sturnella neglecta*)
		Red-winged Blackbird (*Agelaius phoeniceus*)
		Dickcissel (*Spiza americana*)
		Grasshopper Sparrow (*Ammodramus savannarum*)
Agriculture	Grassland edge	Swainson's Hawk (*Buteo swainsoni*)
		Ring-necked Pheasant (*Phasianus colchicus*)
		Vesper Sparrow (*Pooecetes gramineus*)
		Field Sparrow (*Spizella pusilla*)
		Lark Sparrow (*Chondestes grammacus*)
	Forest edge/generalist	Red-tailed Hawk (*Buteo jamaicensis*)
		American Kestrel (*Falco sparverius*)
		Mourning Dove (*Zenaida macroura*)
		Screech Owl (*Otus asio*)
		Common Flicker (*Colaptes auratus*)
		Red-headed Woodpecker (*Melanerpes erythrocephalus*)
		Red-bellied Woodpecker (*Melanerpes carolinus*)
		Eastern Kingbird (*Tyrannus tyrannus*)
		Western Kingbird (*Tyrannus verticalis*)
		Blue Jay (*Cyanocitta cristata*)
		American Crow (*Corvus brachyrhynchos*)
		Northern Mockingbird (*Mimus polyglottos*)
		American Robin (*Turdus migratorius*)
		Eastern Bluebird (*Sialia sialis*)
		European Starling (*Sturnus vulgaris*)
		House Sparrow (*Passer domesticus*)
		Brown-headed Cowbird (*Molothrus ater*)
		Common Grackle (*Quiscalus quiscula*)
		Orchard Oriole (*Icterus spurius*)
		Northern Oriole (*Icterus galbula*)
		American Goldfinch (*Spinus tristis*)
		Chipping Sparrow (*Spizella passerina*)
Wildlife	Forest edge/generalist	Northern Bobwhite (*Colinus virginianus*)
		Willow Flycatcher (*Empidonax traillii*)
		Black-capped Chickadee (*Parus atricapillus*)
		House Wren (*Troglodytes aedon*)
		Gray Catbird (*Dumetella carolinensis*)
		Brown Thrasher (*Toxostoma rufum*)
		Loggerhead Shrike (*Lanius ludovicianus*)
		Bell Vireo (*Vireo griseus*)
		Northern Cardinal (*Cardinalis cardinalis*)
		Indigo Bunting (*Passerina cyanea*)
		Song Sparrow (*Melospiza melodea*)

Note: Birds are grouped by habitat response guilds potentially occurring as a result of the adoption of three policy scenarios: Baseline (no shelterbelts), Agriculture (single row shelterbelt comprised of deciduous trees), and Wildlife (5-row shelterbelt configuration consisting of shrubs, deciduous trees, and conifers).

Table 3. Landscape metrics selected for use as independent variables (X_i) in the analysis of avian habitat relationships from selected BBS routes in east-central Nebraska and associated correlates.

X_i	Independent variable	Abbreviation	Correlates
X_1	Total woods %	ALLWD	Habitat layer index Row crop % Grassland %
X_2	Edge density	EDGDEN	Total Edge Row crop % Contagion Dominance Diversity Interspersion
X_3	Woody edge %	WEDGE	none
X_4	Farmstead %	FARM	none

Note: Variables were selected from groups of highly correlated metrics (Pearson $r > 0.90$) based on their potential to be influenced by shelterbelt policy scenarios.

Forest-interior guild were also rarely observed, occurring in small numbers on only nine out of 16 route segments and constituting only three percent of the species observed.

Using landscape variables to predict measures of breeding bird diversity

Predictors of species richness

The total number of bird species (SPRICH) along each BBS route was best predicted by the total woods percentage (ALLWD) within the landscape (Table 5). The total woods percentage would be expected to increase as shelterbelts are incorporated in the landscape. The increase in the proportion of the landscape in woods provides for greater habitat diversity, increasing the potential niches and nesting sites for a greater number of bird species.

Total woods (ALLWD) also served as the best predictor of bird species richness within the Forest-edge/generalist (FEGSR), Grassland-edge (GESR) and Forest-interior (FISR) guilds. A greater proportion of breeding birds are classified as Forest-edge/generalist (FEGSR), which partially explains the relationship with the total woods variable. Edge density (EDGDEN) also served as a predictor of species richness for birds in the Grassland-edge (GESR) guild. No landscape variables met the $P = 0.15$ threshold for predicting species richness for the Grassland-field guild (GRSR).

Table 4. Values of landscape metrics calculated by HAMS for the dryland and irrigated representative farm core areas and their surrounding landscapes for the Baseline scenarios in Saunders County, Nebraska.

Metric	Dryland		Irrigated	
	Core area	Landscape	Core area	Landscape
Size (ha)	225	2,302	195	2,441
Contagion	0.68	0.65	0.83	0.89
Dominance	0.42	0.39	0.70	0.82
Diversity	0.57	0.59	0.25	0.13
Interspersion	0.02	0.03	0.01	0.01
Woodlot %	9.30	10.41	3.51	1.48
Individual tree %	1.31	2.14	0.51	0.74
Row crop %	57.29	56.50	86.38	93.46
Grassland %	30.47	28.30	7.64	2.21
Water %	0.18	0.13	0.00	0.00
Farmstead %	1.45	2.53	1.97	2.11
Total woods %[a]	10.61	12.55	4.01	2.22
Total edge (km)[a]	8.9	296.1	7.3	119.3
Edge density (m/ha)[a]	101	129	74	49
Woody edge %[a]	61.06	63.86	49.04	41.76

[a] Variables defined from HAMS Shared Edge Distance metric. Total edge equals the sum of all shared edge distances; Edge Density equals total edge divided by size; and woody edge % is the proportion of Total Edge wherein one class is woods.

Table 5. Landscape variables identified through stepwise regression as the best predictors (X) of avian community measures (Y_i) with their parameter estimates (A, B), R^2, F, and P values.

Y_i	Abbreviation	A	B	X	R^2	F	P
$Y_{1.11}$	SPRICH	26.99	0.62	ALLWD	0.52	14.90	0.0017
$Y_{1.12}$	FEGSR	21.85	0.41	ALLWD	0.37	8.15	0.0127
$Y_{1.13}$	FISR	0.10	0.13	ALLWD	0.56	17.87	0.0008
$Y_{1.14}$	GRSR	–	–	none	–	–	–
$Y_{1.15}$	GESR	1.89	0.12 –0.02	ALLWD EDGDEN	0.37	3.51	0.0800
$Y_{1.21}$	ABUND	232.40	1.74	EDGDEN	0.18	3.13	0.0987
$Y_{1.22}$	FEGRA	116.69	2.08	EDGDEN	0.28	5.51	0.0341
$Y_{1.23}$	FIRA	–2.37	0.04	EDGDEN	0.26	4.85	0.0449
$Y_{1.24}$	GRRA	–	–	none	–	–	–
$Y_{1.25}$	GERA	53.23	–0.36	EDGDEN	0.26	4.87	0.0446

Predictors of abundance

Edge density (EDGDEN) served as the best predictor of total abundance (ABUND) of birds for each BBS route and for the Forest-edge/generalist (FEGRA), Forest-interior (FIRA) and Grassland-edge guilds (GERA). No landscape variables met the $P = 0.15$ threshold for predicting the abundance for birds within the Grassland-field guild (GRRA).

From these analyses, landscape variables were found to be predictors of certain bird diversity measures (Table 5). However, these landscape variables did not account for a large proportion of the variance of the species richness and abundance values. Total woods percentages (ALLWD) captured over 50% of the total species richness but predictors for other diversity measures performed poorly. For instance, EDGDEN accounted for less than 30% of the variance of bird abundance values (total abundance or abundance within guilds). Despite these shortcomings, landscape metrics were found to influence the bird community and were used to provide insight into the changes which occur as a result of the two policy scenarios promoting shelterbelts.

Farm- and landscape-level analysis

As expected, simulating the Agricultural and Wildlife scenarios on each farm and surrounding landscape increased the values of predictor metrics relative to the Baseline (Table 6). Of particular note were the lower edge density (EDGDEN) values on both RFCA's and their surrounding landscapes resulting from the simulation of the Wildlife scenario. Edge density values were entirely dependent on the ratio of patch edge to patch area. Thus, implementation of the Agricultural scenario (characterized by smaller patches of single-row shelterbelts) resulted in higher edge density values relative to implementation of the Wildlife scenario.

The models developed from the BBS data (see Table 5) predicted changes which would occur within the bird community on the RFCA's and their surrounding landscapes as a result of implementing the shelterbelt scenarios (Table 7). Total species richness and relative abundance measures increased under each scenario, but response varied between guilds. Species richness and relative abundance values for the Forest-edge/generalist guild increased under all scenarios, while these values for the Grassland-edge guild tended to be negatively influenced. Although the Forest-interior guild had the highest percent increase as a result of adding shelterbelts to the landscape, the extremely small number of species and individuals predicted for the Baseline scenario made any increase in absolute terms a large one in relative terms. As no landscape variables were found to be predictors for the Grassland-field guild, no response could be predicted.

Table 6. Changes in predictor landscape metrics[a] on the representative farm core areas in east-central Nebraska and their surrounding landscapes as a result of implementation of the three policy scenarios: Baseline (existing land cover), Agricultural (adding single row shelterbelts), and Wildlife (adding 5-row shelterbelts).

Representative farm	Metric	Core area			Landscape		
		Base-line	Agriculture (% incr.)	Wildlife (% incr.)	Base-line	Agriculture (% incr.)	Wildlife (% incr.)
Irrigated	Total woods (%)	4.0	5.4 (35)	12.5 (212)	2.2	3.6 (64)	10.6 (382)
	Edge density (m/ha)	74	101 (36)	95 (28)	49	85 (73)	83 (69)
Dryland	Total woods (%)	10.6	12.5 (18)	18.6 (75)	12.6	14.1 (13)	18.7 (50)
	Edge density (m/ha)	100	144 (44)	120 (20)	129	170 (22)	144 (12)

[a] Change is measured as the percent increase in a particular metric over its baseline value due to the implementation of a particular policy scenario.

Table 7. Predicted changes in bird community metrics[a] on the representative farm core areas in east-central Nebraska and their surrounding landscapes as a result of implementation of the three policy scenarios: Baseline (existing land cover), Agricultural (adding single row shelterbelts), and Wildlife (adding 5-row shelterbelts).

Representative farm	Metric[b]	Core area			Landscape		
		Base-line	Agriculture (% incr.)	Wildlife (% incr.)	Base-line	Agriculture (% incr.)	Wildlife (% incr.)
Irrigated	SPRICH	29.5	30.3 (2.9)	34.8 (17.9)	28.4	29.2 (3.0)	33.6 (18.3)
	FEGSR	23.5	24.1 (2.4)	27.0 (14.9)	22.8	23.3 (2.5)	26.2 (15.1)
	FISR	0.6	0.8 (29.1)	1.7 (178.5)	0.4	0.6 (46.5)	1.5 (280.7)
	GESR	0.9	0.5 (–41.9)	1.5 (67.7)	1.3	0.8 (–38.3)	1.7 (29.7)
	ABUND	361.2	408.1 (13.0)	397.7 (10.1)	305.1	363.6 (19.2)	358.5 (17.5)
	FEGRA	270.6	326.8 (20.8)	314.3 (16.1)	203.6	273.5 (34.4)	267.4 (31.4)
	FIRA	0.6	1.7 (183.1)	1.4 (142.4)	0.0	0.6 (60.0)	0.5 (50.0)
	GERA	26.6	16.9 (–36.6)	19.0 (–28.4)	38.2	26.1 (–31.7)	27.1 (–28.9)
Dryland	SPRICH	33.6	34.7 (3.5)	38.5 (14.7)	34.8	35.7 (2.8)	38.6 (11.0)
	FEGSR	26.2	27.0 (3.0)	29.5 (12.5)	27.0	27.6 (2.4)	29.5 (9.3)
	FISR	1.5	1.7 (16.7)	2.5 (70.1)	1.7	1.9 (11.6)	2.5 (46.2)
	GESR	1.2	0.5 (–56.1)	1.7 (47.9)	2.1	2.0 (–4.5)	2.7 (28.3)
	ABUND	406.4	483.0 (18.8)	441.2 (8.6)	343.5	368.0 (7.1)	355.5 (3.5)
	FEGRA	324.7	416.2 (28.2)	366.3 (12.8)	249.5	278.7 (11.7)	263.9 (5.8)
	FIRA	1.6	3.4 (108.0)	2.4 (49.1)	0.2	0.7 (304.8)	0.5 (149.7)
	GERA	17.2	1.4 (–91.9)	10.0 (–41.8)	30.2	25.2 (–16.7)	27.8 (–8.2)

[a] Change is measured as the percent increase in a particular metric over its baseline value due to the implementation of a particular policy scenario.
[b] SPRICH and ABUND denote total species richness and relative abundance; FEGSR, FEGRA, FISR, FIRA, GESR, and GERA denote species richness and relative abundance within the Forest-edge/generalist, Forest-interior, and Grassland-edge guilds, respectively. No models predicted Grassland-field guild (GR) species richness or relative abundance.

Discussion and conclusions

The representative farm process provided a mechanism for evaluating the influence of shelterbelt policies on the bird community at the farm-level and the ability to project those impacts on a larger landscape. Implementing the Agricultural and Wildlife shelterbelt policy scenarios on both dryland and irrigated RFCAs resulted in changes in land use composition and other landscape measures, directly influencing breeding bird species richness and the patterns of community composition. Poulsen (1997) found that landscape heterogeneity was an important factor influencing bird species distribution patterns within agricultural landscapes. Heterogeneity increased as a result of implementing shelterbelt scenarios on the dryland landscape and to a greater degree on the irrigated landscape. Woody habitat within agricultural systems dominated by row crops increases landscape diversity by providing edge with trees and shrubs.

Data from the four BBS routes provided a mechanism to investigate bird-habitat relationships in east-central Nebraska. Although sample size was relatively low, these landscapes provided a representative sample of habitats available in that portion of the state. The amount of woodland cover was confirmed to be a significant determinant of bird species richness on the BBS routes and therefore was important in influencing the bird community at both the farm- and landscape-level. Landscape metrics which most influenced bird community composition on the BBS routes included total woods and edge density values.

One outcome resulting from the Agricultural and Wildlife scenarios was an increase in woody edge habitats, which was effectively quantified by the edge density metric. This measure was entirely dependent on the ratio of patch edge to patch area. Thus, the landscape created by the Agricultural scenario (smaller patches resulting from single row shelterbelts) had higher edge density values than those landscapes generated by the Wildlife scenario (larger patches resulting from the 5-row design). Edge density values served as measures of the homogeneity and heterogeneity of the landscape as influenced by the shelterbelt scenarios. Edge density was found to be the best predictor of relative abundance for birds within the Forest-edge/generalist and Grassland-edge guilds, as species from these guilds were significantly more common in heterogeneous areas (see Poulsen, 1997). Birds within the Grassland-field guild, many of which are area sensitive grassland species, would be expected to predominate on relatively unfragmented, homogeneous landscapes made up of large proportions of grassland areas (Herkert, 1994). These areas would be characterized by low edge density values (and corresponding high contagion and dominance values).

Results also indicated that total species richness of birds on these particular Nebraska farmlands was primarily controlled by the total amount of woodland cover. Any increase in species richness, as predicted by higher total woods percentages, will most likely be due to the addition of new species more associated with woody vegetation and edges (Forest-edge/generalists), with few species within the other guilds being positively affected. Using BBS route data, Igl and Johnson (1997) found that bird species which increased in numbers in the Great Plains were those associated with human structures and woody vegetation, while grassland associated bird species exhibited a significant decline. Likewise, Knopf (1994) and Herkert (1994) reported grassland bird species to be negatively correlated with percent forest cover and the conversion and fragmentation of the prairie ecosystem.

Guilds can be described in a variety of ways; we defined them *a priori* based on nesting requirements reasoning that nesting cover is likely to be a limiting factor for most birds within intensively cropped areas. Birds within each guild were assumed to respond equally to habitat modifications, such as those resulting from the implementation of shelterbelts. Violations of this assumption are possible given variations in microsite characteristics (Verner, 1984) between shelterbelts of the same type (e.g., Agricultural). However, the general nature of the habitat perturbations we simulated (i.e., substituting woody vegetation for row crops) made it unnecessary to define guilds by finer habitat distinctions. Bird response can be expected to differ between the Agricultural and Wildlife shelterbelts. The addition of shrubs to the shelterbelt design (e.g., Wildlife scenario) potentially improves their value to birds during particular seasons by increasing the availability of food and cover with the addition of multiple rows which increases width (Johnson and Beck, 1988). Yahner (1982) found that birds also partition resource use in shelterbelts along a gradient of vertical complexity. The addition of shrubs increases the complexity of vertical structure, which provides different niche opportunities for bird species.

Total woods percentages served as the best predictor of bird species richness for the Forest-interior guild. It was assumed that the value of small patches of woods created by shelterbelt policy scenarios (i.e., single-row or 5-row shelterbelts) provided very limited nesting habitat for Forest-interior birds in landscapes that completely lack extensive tracts of woody habitats (Robinson et al., 1995). Forest-interior birds were only marginally projected to be positively influenced by policies promoting shelterbelts at the farm-level. This was primarily due to the greater edge density values resulting from the adoption of each of the shelterbelt scenarios. The classification of species according to their preference for forest interior habitat or avoidance of small woodland patches tends to focus attention at the local scale. However, as Villard et al. (1995) have suggested, processes underlying these phenomena may take place over landscape scales. Villard et al. (1995) noted that woody patch occupancy by bird species tends to be influenced by the larger context of the landscape (proximity to other local populations), rather than by local characteristics.

It must be noted that shelterbelts are only one of the components of the agricultural landscape which influence bird community dynamics. Other important components influence the bird community including land use choices, cultural practices and intensity of crop production systems, as well as the management of field borders. Bird species utilizing one of these habitat elements (i.e., woodlands, row crops or fields) at the farm-level also are influenced to some extent by the regional land use and landscape patterns occurring at much larger scales (see Villard, 1998).

A problem of scale in guild definition was reflected in the fact that none of the landscape variables used at this level of investigation were found to predict species richness or relative abundance for birds within the Grassland-field guild. Although there are relatively fewer birds within this guild, these species also may be responding to biotic factors (i.e., habitat changes as previously discussed) as well as to abiotic factors on both a finer as well as a broader scale than was measured. Because native grasslands and prairie ecosystems have been converted to other uses in the Great Plains, grassland birds species have declined over much of their range and represent a community of high conservation concern (Herkert, 1994). Grassland fragmentation by woody vegetation may negatively affect reproductive success of grassland birds (Knopf, 1994). However, the conversion of grassland and prairie habitats to agricultural lands is viewed as the primary factor explaining the trend of declining grassland bird populations. Although species richness may be increased locally, policies promoting shelterbelts on the agricultural landscape would increase the relative amounts of woody vegetation and edge habitats potentially causing further declines in the abundance of birds in the Grassland-field guild. Because agricultural policies potentially affect species composition of the landscape across broad scales, it is important to consider the interrelationships of land management and bird community structure at a larger, regional scale when developing agricultural policy.

The shelterbelt policies were simulated uniformly on each of the landscapes surrounding the irrigated and dryland farms. Thus, the predicted effects of the policy scenarios on the bird community did not differ significantly at the landscape-level from the core farms. However, an individual farmer's willingness to adopt either of the three shelterbelt scenarios is influenced by a diverse set of conditions. Erickson and DeYoung (1994) suggested that the management of trees and shelterbelts in the rural landscape is influenced not only by economic factors, but also by rural landscape aesthetic preferences, pro-conservation attitudes, intrinsic satisfactions, perceived benefits of woodlots and shelterbelts, and overall landscape patterns beyond farm boundaries. These factors ultimately influence farm-level habitats but also larger landscape patterns which, in turn, influence the distribution and composition of the bird community. The objective of this study was to develop a decision-making system for farm-level policy analysis which had the capability of projecting the influence of agricultural policies utilizing shelterbelts on breeding bird communities. Simulating bird community dynamics under these policy scenarios required the ability to model landscape change and to project the responses of bird guilds to these changes so that wildlife considerations could be integrated into economic and environmental models (Cassidy, 1998; Pierce, 1998) for agricultural policy analysis. Results from this study have shown that a farm-level modeling system can provide both qualitative and quantitative information to policy-makers and landowners on the potential impacts that agroforestry programs have on wildlife habitats. As a result of this initial effort, land stewardship goals and opportunities for wildlife will hopefully be a more visible alternative within future agricultural programs as well as during the evaluation of agricultural policies at the farm-level.

The modeling system also provides a framework from which additional wildlife research needs to be conducted, so that more reliable information can be integrated into farm-level policy analysis, thereby improving the interface between applied farm-level economic and ecological models. Future large-scale investigations are needed which examine the cumulative influence of land use activities on bird communities within the agricultural landscape. Research needs to be conducted within these agroecosystems to critically assess which habitats, cropping system schemes, and landscape structure characteristics represent ecological traps for grassland bird species and which do not. Furthermore, investigations need to be conducted which address the size and location of grassland habitats relative to other land classes so that their value in supporting grassland species richness as well as contributing to the overall population can be maximized. These investigations should complement observations at more local scales so that the placement and design of conservation practices, including those that utilize shelterbelts, can be targeted to specific sites which will be most beneficial, not only for agronomic purposes but to the bird community and the wildlife community as a whole.

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