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density of the shelterbelt. In the past these descriptions have been expressed primarily in two dimensions. Most recently, Wang and Takle (1995; 1996; 1997) have developed a turbulence model which requires a three dimensional measure of shelterbelt structure. Due to the difficulty in describing an actual shelterbelt, their study used hypothetical shelterbelts with a given structure. This study describes the vertical distribution of surface area of 30 year old green ash trees growing under the competition of a shelterbelt situation. The field data were obtained by carefully dissecting 18 green ash trees with different diameters and heights. Using these field data, the vertical distributions of trunk and branch surface areas were fitted to the third order polynomial and the Beta distribution, respectively. The derivations of the vertical distributions of leaf and seed surface areas based on green ash architecture show that the surface areas of both components comply with the Beta distribution. The measured vertical distributions of both components were fitted to the derived distribution. The developed equations to describe the vertical distributions of surface areas of these four components can be used to describe the 3-dimensional aerodynamic structure of a shelterbelt using easily measured tree characteristics such as DBH, height and the crown diameter.

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LANDSCAPE PATTERNS AND THEIR INFLUENCE ON BIRD COMMUNITIES RESULTING FROM AGRICULTURAL POLICIES PROMOTING SHELTERBELTS IN EASTERN NEBRASKA

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Keywords: conservation, wildlife, windbreaks

ABSTRACT

Evolving agricultural policies and technologies have influenced land management practices within agroecosystems, impacting available habitats for many species of wildlife. Increasing available wildlife habitat and enhancing habitat quality has become an explicit objective of existing agricultural policy. Thus, there is renewed focus on utilizing shelterbelt agroforestry systems as a tool to achieve conservation goals in the northern Great Plains. Two representative farms - a 700-acre dryland and 1260-acre 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 the Agricultural or Wildlife shelterbelt scenario. The percent total woods 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. Other landscape metrics which influenced the bird community composition on BBS routes were woody edge percentages and edge density values. Policies promoting shelterbelts at the farm-level as well as on the agricultural landscape create edge habitats which ultimately favor birds within the Forest-edge/generalist and Grassland-edge guilds, 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. Emerging agricultural and conservation policies (USDA, 1996) have incorporated requirements to measure the impacts of specific programs on wildlife habitat as the 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 (Barrett et al., 1990). 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, 1983; Best et al., 1995).

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. Agroforestry land management systems, which exploit the interactions between trees and crops (including livestock), can potentially bridge the gap between production agriculture and natural resource management. According to Garrett et al. (1994), properly designed agroforestry systems patterned after natural ecosystems yield many benefits, including increased landscape diversification of row crop agricultural systems through the establishment of windbreaks, shelterbelts and woody hedgerows, ultimately leading to increased biodiversity within these landscapes.

In intensively farmed areas, windbreaks often provide the only wooded habitat in the landscape and thereby potentially increase wildlife species diversity and abundance. Martin (1980), Yahner (1983), and Johnson and Beck (1988) have confirmed the importance of shelterbelts for a variety of bird species, while Schroeder et al. (1992) and Poulsen (1997) identified characteristics such as total area, perimeter, 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) and Poulsen (1997) have 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. Wildlife management and natural resource policy decisions are increasingly being made at the landscape-level (Brady and Flather, 1994). Therefore, an understanding of the relationship between modification and the pattern of land classes within an agroecosystem may serve to minimize potential impacts and enhance the complement of wildlife species.

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 (Lillesand and Kiefer, 1994) or through the use of digital orthophotoquads (USDA, 1995). Landscape composition and pattern can be described by a variety of metrics (O'Neill et al., 1988), including spatial heterogeneity, fragmentation, edge characteristics and connectivity. Each of these metrics, as well as landscape characteristics, such as patch size, edge length, and spatial arrangement of cover types, can be significantly altered as shelterbelt

agroforestry systems become integrated into the agroecosystem.

Purpose and Objectives

Agricultural policies promoting the integration of shelterbelt agroforestry systems into the Great Plains agroecosystem have the potential to influence both the vertical habitat structure and the spatial pattern of the landscape, both influencing breeding bird species richness. Allen and Hoekstra (1992) and Freemark (1995) have indicated that 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 - the distribution and pattern of croplands and non-croplands and their influence on bird species richness and community distribution and composition.

The overall purpose of this study is to develop a methodology capable of evaluating the changes in wildlife habitat that occurs 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 (see 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 modification 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 (Hansen et al., 1993; Roseberry and Hao, 1996).

Methodology

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 (USDA, 1981). 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 (USDA, 1996). Principle crops include corn, soybeans, grain sorghum, alfalfa, and oats (USDA, 1981). 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 Nebraska, pers. comm.).

Characteristics of the Representative Farms

Two representative farms were developed in Saunders County, Nebraska, to evaluate the effects of various policy options utilizing shelterbelts on the economic viability of the farm, as well as to determine the resulting environmental implications and assess the impacts to wildlife habitats. Whether or not irrigation is used for the production of row crops is an important factor which can be used to describe farms in this portion of Nebraska, as the varied topography prevents widespread use irrigation equipment and the use of such equipment determines field sizes (K. Glewen, Univ. of Nebraska, pers. comm.). Thus, the farms in this area were classified as either "dryland" or "irrigated" and one representative farm for each system was constructed. The baseline representative farms do not include shelterbelts, however, policy scenarios were developed that included the use of shelterbelt systems on the landscape to some degree (Cassidy, 1998).

The dryland representative farm was located in western Saunders County and was 700 acres in size; with approximately 570 acres of crops, 100 acres of pasture, and 30 acres of woodlands dispersed across the farm. During the panel farm process it was determined that 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 and was comprised of 1240 acres of cropland: 620 acres of corn and 620 acres 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.

Development of the Representative Farm Scenarios

Three landscape scenarios were developed from which economic, environmental, and wildlife assessments were conducted (Cassidy, 1998; Pierce, 1998). These landscapes resulted from three different agricultural policy parameters: (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 would be strategically utilized for optimal agronomic benefits; and (3) the Wildlife scenario, a shelterbelt consisting of a 5-row coniferous/deciduous tree/shrub mix for enhanced wildlife habitat. A GIS was used describe the existing field conditions as well as to simulate the strategic placement of the two shelterbelt scenarios. A description of the two shelterbelt scenarios used for policy analysis follows.

Agricultural Scenario

- developed to reflect an optimal shelterbelt system based on the objective of increasing net farm income through increased crop yields as a result of microclimate modification
- utilized deciduous trees in a single, 16 feet width row configuration with 12 feet spacing between the trees; at maturity, the trees are expected to reach a height of 30 feet; the useful lifespan of the shelterbelt is assumed to be 50 years

Through the use of a GIS, exterior and interior shelterbelts were placed strategically onto the fields to obtain the desired crop production goals following a process described by Cassidy (1998). At the farm-level, exterior shelterbelts were placed on the southern and western field borders. Interior shelterbelts were placed within a field at widths to achieve crop production goals and as conditions warranted. Shelterbelt placement on the landscape followed the same pattern used at the farm-level, with the assumption that each farmer incorporated single-row shelterbelts on each cropfield, as the condition warranted.

Wildlife Scenario

- developed to reflect a shelterbelt system with more optimal benefits to wildlife; increasing crop yields was a secondary consideration
- utilized 5 rows of trees and shrubs; at maturity, the trees are expected to reach a height of 30 feet; the useful life of the shelterbelt is assumed to be 50 years.
- The total width of the shelterbelt is 128 feet, comprised of the following (beginning from the windward side):

Row 1	Shrubs planted at a spacing of 6 feet
Row 2	One deciduous tree at a 10 feet spacing alternating with a coniferous tree at an 8 feet spacing
Row 3	Same as Row #2
Row 4	Small deciduous trees planted at an 8feet spacing
Row 5	Same as Row #1

Exterior shelterbelts were placed on the southern and western field borders. No interior shelterbelts were incorporated on the either farm or surrounding landscape.

Habitat Analysis Methods

Methods of Analysis to Describe Landscapes

Landscape characteristics within a 9-square-mile (23.3 square kilometer) area around each representative farm and a 0.25 mile radius around each BBS route were digitized from full resolution (1 m^2) digital orthophotoquads (DOQ, Spring 1993, USDA/NRCS, Lincoln, NB) using ARC/INFO (ESRI, 1995). Land cover was classified into six cover classes: (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. Cover class designations were achieved using a combination of ground truthing, and visual interpretation of high altitude color infrared (CIR) photography (scale 1:12,000) and the DOQs.

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.

Each BBS route was divided into five equal sections corresponding with divisions (pages) in the census data. Vector polygon coverages for each representative farm, surrounding landscape and BBS route page were converted to rasters and subsequently imported into the Habitat Analysis and Modeling System (HAMS) Version 1.0 (Roseberry and Hao, 1995) 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 (see Roseberry and Hao, 1995). The composition and spatial structure of the existing landscape image surrounding each RFCA (i.e., Baseline policy scenario) as well as each of the alternative landscape images which resulted from the shelterbelt policy scenarios (i.e., Agricultural and Wildlife policy scenario) were quantified with selected landscape metrics provided by HAMS (Table 1).

Development of a Species Generator Model

A Species Generator Model, developed from species lists of birds whose breeding range overlapped that of the study area (Johnsgard, 1979), was created to describe the avian community which is associated with a particular habitat type. The qualitative model was developed to project the change which occurs within the avian community at the farm- and landscape-level in eastern

Table 1. Description of landscape metrics calculated by 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, described by Li and Reynolds (1993), 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 (O'Neill et al. 1988).
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 as described by O'Neill et al. (1988) and Turner (1989).
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 as described by McGarigal and Marks (1994).
Interspersion	The ratio of the total number of connections between pixels of different land cover classes divided by the maximum possible number of connections (Heinen and Cross 1983).
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).

Nebraska as a result of implementing either the Baseline, Agricultural or Wildlife shelterbelt scenarios at maturity (Table 2). 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 (Johnsgard, 1979; Ehrlich et al.,1988).

Breeding birds found among the terrestrial habitats within the study area were classified as grassland-field, grassland-edge, forest-edge and generalist, and forest-interior species to provide the best approximation of specific habitat requirements during the breeding season. Avian point-count data, developed from recent shelterbelt studies in eastern Nebraska (Fitzmaurice, 1995; Poulsen, 1997), were utilized to project the bird species expected to occur on the representative farms for each of the proposed shelterbelt policy scenarios (Agricultural, Wildlife). The data provided by these studies did not distinguish between bird use of single-row shelterbelts (i.e., as reflected in the Agricultural scenario) or multiple-row shelterbelts (i.e., as reflected in the Wildlife scenario).

Since the creation of edge habitats through the use of shelterbelts within landscapes dominated by large proportions of row crops can be described as a severe habitat change, 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 individuals of all species in a guild were used to measure the guild response resulting from the implementation of a particular policy.

Use of Bird Data Provided by 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, U.S. 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 25-mile roadside surveys, each containing 50 stops at 0.5-mile intervals. Each active BBS route is censused 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, while the finest temporal resolution of the data was a year.

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 until 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. Full DOQ coverage for the four selected routes was unavailable, thus only 16 of the potential 20 pages of data were analyzed.

Poulsen (1997) examined data from 41 BBS routes in Nebraska during a 10-year period (1981-1990) 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 four BBS routes were examined and annual variations were relatively small, bird data were summed for all years to obtain a single value to reduce the potential influence of observer error. HAMS was utilized to provide landscape metrics for each route segment (i.e., census page).

Table 2. Subset list of bird species, grouped by habitat response guild, which would be expected to inhabit the study area with no shelterbelts, agriculture shelterbelts, and wildlife shelterbelts[1] 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[2]	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*)

[1]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).

[2]Bird species listed under the Wildlife scenario include species requiring the Midstory habitat layer, assumed unavailable under the Agriculture scenario. As the Wildlife and Agriculture scenarios share all other habitat layers, birds expected in single row shelterbelts (i.e., listed under the Agriculture scenario) are likewise expected to utilize the 5-row design.

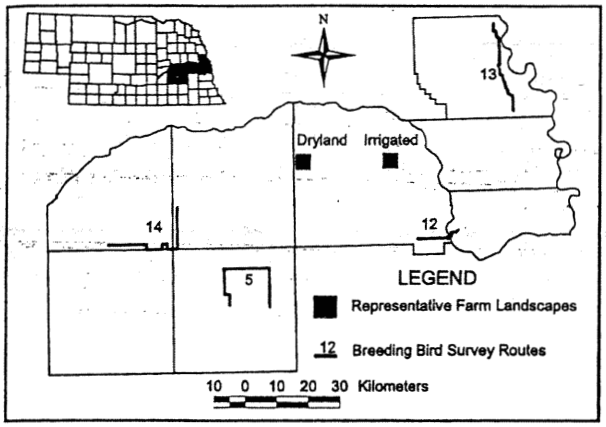

Figure 1. Breeding Bird Survey route locations by representative farm core areas.

Bird species taken from the BBS routes were characterized according to the species' habitat requirements during the breeding season (Johnsgard, 1979; Ehrlich et al., 1988) and associated with one of the habitat response guilds: grassland-field species, grassland-edge species, forest-edge and generalist species, and forest-interior species. The total number of species recorded within each guild were extracted at the page level (equivalent of 10 consecutive stops). In addition, the number of individuals per species were totaled by guild for each page of the BBS routes.

Bird species diversity indices

The following diversity indices were selected to characterize the bird community structure at the page level for each of the BBS routes used for this study:

1. Species richness - the number of species per route or area (i.e., species density, Hurlbert, 1971) without regard to relative species abundance.
2. Margalef diversity (Margalef, 1968) - a richness index (summary statistic) calculated as
$D = (S-1) / \ln N$, where diversity equals the quotient of the number of species observed (S) minus 1, divided by the natural logarithm of the total number of individuals (N). Higher values of this index represent higher diversity of species that are more equitably distributed (Magurran, 1988).
3. Q-statistic (Kempton and Taylor, 1978) - an index(summary statistic) which is a measure of the slope of the line over the interquartile range where the ordinate represents the number of species and the abscissa represents the natural logarithm of the number of individuals. This diversity index is based on the slope of the cumulative species curve in the mid-range of abundances and is defined mathematically as: $Q = S / 2 \log (R2 / R1)$; where S is the total number of species in the sample and R1 and R2 are the lower and upper quartiles of the species abundance distribution. A low value of the Q-statistic represents low diversity. The Q-statistic is an index of evenness (Cotgreave and Harvey, 1994) with good discriminant ability and low sensitivity to sample size (Magurran, 1988).
4. Dominance (McNaughton, 1967) - a summary statistic defined as the quotient of the number of individuals of the two most abundant species divided by the total number of individuals of all species, expressed mathematically as $d = Nmax / N$. This expression is a version of the Berger-Parker index d (Berger and Parker, 1970; May, 1975). Unlike the three indices above, higher values of dominance represent lower diversity, or an ecosystem dominated by a few species. It is independent of species richness and has low sensitivity to sample size (Magurran, 1988).

Magurran (1988) stated the importance of using multiple methods for measuring species diversity. These diversity indices were chosen because each describes different attributes of the species richness and relative abundance pattern of the bird community and have been shown to be generally independent of one another.

Modeling Strategy

Certain landscape metrics were selected from their correlates for use as independent variables in the analysis of avian habitat relationships from the BBS routes in east-central Nebraska used in this study (Table 3). Regression analysis was used to select those landscape metrics (independent variables) which best predicted bird species richness, relative abundance and the diversity summary statistics (dependent variables) on the landscapes surrounding the BBS routes. Contained in Table 3 is a list of those landscape metrics (independent variables) which could be used to potentially predict the dependent variables (Table 4).

Stepwise regression (Draper and Smith, 1981) was used to determine the "best" subset of predictors. SAS (1995) was used to provide regression analysis and to calculate the Pearson product-moment correlation (Neter et al,. 1989) between all variables to determine which ones were highly correlated ($r \geq 0.90$). 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

Description of the Dryland and Irrigated RFCA and Surrounding Landscape

Table 5 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.

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.

Table 4. Observed or derived dependent variables (Y_i) used in the analysis of avian habitat relationships from selected BBS routes in east-central Nebraska.

Y_i	Dependent variable	Abbreviation
$Y_{1.11}$	Total Species Richness	SPRICH
$Y_{1.12}$	Forest Edge/Generalist Species Richness	FEGSR
$Y_{1.13}$	Forest Interior Species Richness	FISR
$Y_{1.14}$	Grassland Species Richness	GRSR
$Y_{1.15}$	Grassland Edge Species Richness	GESR
$Y_{1.21}$	Total Abundance	ABUND
$Y_{1.22}$	Forest Edge/Generalist Relative Abundance	FEGRA
$Y_{1.23}$	Forest Interior Relative Abundance	FIRA
$Y_{1.24}$	Grassland Relative Abundance	GRRA
$Y_{1.25}$	Grassland Edge Relative Abundance	GERA
$Y_{2.1}$	Q-statistic	Q
$Y_{2.2}$	*Margalef Diversity Index*	Mg
$Y_{2.3}$	Dominance Index	D

Table 5. 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.

	Dryland		Irrigated	
Metric	Core area	Land-scape	Core area	Land-scape
Size (ha)	225	2302	195	2441
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 % [1]	10.61	12.55	4.01	2.22
Total Edge (km) [1]	8.9	296.1	7.3	119.3
Edge Density (m/ha)[1]	101	129	74	49
Woody Edge % [1]	61.06	63.86	49.04	41.76

[1] 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.

Description of the Bird Community Structure for Each of the Bbs Route Sections

Table 6 describes the total species richness and relative abundance of birds, as grouped by habitat response guild, at the page-total level within BBS routes. Relationships existed between species richness patterns and the three independent species diversity summary statistics at the page-level. Each of the five BBS route segments with the highest species richness total (i.e., 5b, 12e, 13b, 13c, 13e) also had the highest values for the Margalef diversity index. Four of these BBS route segments (5b, 12e, 13b, 13c) also had the highest values for the Q-statistic (a measure of evenness). Relatively low dominance values (indicating increased species diversity with abundances more evenly distributed) were observed on three of the five BBS route segments (12e, 13b, 13c). BBS route segment 5b exhibited the highest value for Dominance relative to the other four route segments due to a high number of house sparrows observed. No clear relationships existed between total abundance and the other summary statistics describing species richness or measuring species diversity (Table 6).

Table 6. Page-level data for Breeding Bird Survey (BBS) routes in east-central Nebraska, including total species richness, total abundance, and three species diversity measures: Q-statistic (Q), Margalef diversity index (Mg), species dominance (D).

Route segment [1]	Species richness	Total abundance	Q	Mg	D
BBS5a	27	279	7.15	4.44	10.85
BBS5b	33	379	15.37	5.39	11.83
BBS5c		32	8.82	5.38	5.83
BBS5d		28	6.25	4.79	5.41
BBS5e	25	197	6.70	4.54	2.80
BBS12d	28	636	5.95	4.18	20.94
BBS12e	34	331	8.76	5.69	8.11
BBS13b	44	512	12.33	6.89	7.15
BBS13c	41	470	7.8	6.50	10.11
BBS13d	33	770	7.17	4.81	25.03
BBS13e	36	492	7.59	5.65	10.78
BBS14a	24	354	6.08	3.92	16.97
BBS14b	24	395	5.33	3.85	12.67
BBS14c	30	459	6.30	4.73	9.83
BBS14d	28	296	6.44	4.74	8.25
BBS14e	30	350	7.71	4.95	12.21

[1] Each Route Segment equates to a page of BBS data (10 stops).

There was considerable variation in the total species richness and relative abundance of birds between BBS routes within particular guilds (Table 7). The Forest-edge/generalist guild dominated the bird community structure on each BBS route. The variation of total species richness and total abundance on the BBS route segments was primarily due to the influence of the Forest-edge/generalist guild. At the page-total level, there was little variation in species richness of the Grassland-field, Grassland-edge and/or Forest-interior guilds. The Grassland-field and Grassland-edge guilds contained only a few species which were commonly observed. Birds within the Forest-interior guild were rarely observed along the BBS routes, occurring in small numbers on only 9 out of 16 route segments.

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 8). 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, which partially explains the relationship with the total woods variable. Edge density (EDGDEN) also served as a predictor of species richness for the Grassland-edge guild. No landscape variables met the P = 0.15 threshold for predicting species richness for the Grassland-field guild (GRSR).

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).

Evenness of the bird community, as described by the Q-statistic, was positively related to the percent woody edge (WEDGE) found at the BBS route page-level. As the proportion of total edge which is woods (i.e., woody edge) increased, the proportions of other edge combinations (e.g., grasslands and row crops) within the landscape decreased, serving to potentially increase the relative abundance of additional birds which are associated with woodlands.

None of the three landscape variables (ALLWD, EDGDEN, WEDGE) were significant predictors of the Dominance index (D). Route segments with high dominance values reflected the presence of a few bird species occurring in large numbers which were associated with human habitation (Pierce, 1998).

From these analyses, landscape variables were found to be predictors of certain bird diversity measures. 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 richness measures (total species richness and Margalef diversity), 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) while WEDGE percentages were only able to account for 19% of the variations in the Q-statistic (Table 8). 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.

Table 7. Total species richness (SR) and relative abundance (RA) of birds, grouped by habitat response guilds, on Breeding Bird Survey (BBS) route segments in east-central Nebraska 1992 - 1994.

Route segments	Forest interior		Forest edge / Generalists		Grassland		Grassland edge		Page total	
	SR	RA	SR	RA	SR	RA	SR	RA	SR	RA
5a	0	0	20	207	5	69	2	3	27	279
5b	2	10	26	314	4	50	1	5	33	379
5c	0	0	26	261	5	51	1	5	32	317
5d	0	0	22	195	5	78	1	8	28	281
5e	0	0	19	145	3	48	3	4	25	197
12d	1	1	22	582	5	53	0	0	28	636
12e	2	2	26	266	5	59	1	4	34	331
13b	4	7	33	421	5	80	2	4	44	512
13c	2	3	32	413	5	42	2	12	41	470
13d	1	1	28	668	4	101	0	0	33	770
13e	1	1	30	393	5	98	0	0	36	492
14a	1	1	19	233	3	42	1	78	24	354
14b	0	0	19	258	4	77	1	60	24	395
14c	0	0	25	317	4	81	1	61	30	459
14d	0	0	23	248	3	25	2	23	28	296
14e	1	1	23	300	5	42	1	7	30	350

Table 8. 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
$Y_{2.1}$	Q	4.85	0.07	WEDGE	0.19	3.20	0.0954
$Y_{2.2}$	Mg	4.43	0.09	ALLWD	0.50	13.80	0.0023
$Y_{2.3}$	D	--	--	NONE	--	--	-

Farm- and Landscape-level Analysis

As expected, simulating the Agricultural and Wildlife shelterbelt scenarios on each farm and surrounding landscape increased the values of predictor metrics relative to the Baseline (Table 9).

Of particular note were the lower edge density values on both RFCA's and their surrounding landscapes resulting from the simulation of the 5-row Wildlife scenario. Edge density values were entirely dependent on the ratio of patch area to patch edge. Thus, implementation of the Agricultural scenario (characterized by smaller patches of single-row shelterbelts) resulted in higher edge density values and woody edge percentages relative to implementation of the Wildlife scenario.

Discussion

Determinants of the Breeding Bird Community Resulting From Shelterbelt Policy Scenarios

The representative farm process provided a mechanism for evaluating the influence of shelterbelt policies on the bird community at the farm-level and projecting those impacts on a larger landscape. The implementation of the Agricultural and Wildlife shelterbelt policy scenarios on both the dryland and irrigated RFCAs resulted in changes in land use composition and other landscape measures which directly influence breeding bird species richness and patterns of community composition. Poulsen (1997) found that landscape heterogeneity was an important factor influencing bird species distribution patterns within agricultural landscapes. A more heterogenous landscape results from implementing either shelterbelt scenario. Woody habitat within agricultural systems dominated by row crops increases landscape diversity by providing edge with trees and shrubs.

Land Cover Type

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 woody edge percentages and edge density values. The percent total woods on the landscapes surrounding the BBS routes was the best predictor of total species richness of the bird community. One outcome resulting from both of the shelterbelt scenarios was an increase in habitat edge, which was effectively quantified by the edge density metric. This measure was entirely dependent on the ratio of patch area to patch edge. Thus, the landscape created by the Agricultural shelterbelt 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 would be expected to predominate on homogenous areas characterized by low edge density values (and corresponding high contagion and dominance values) as exemplified by the existing irrigated RFCA and landscape.

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, with fewer species within the Grassland-field guild being positively affected. Igl and Johnson (1997) also documented (from BBS route data) that species exhibiting significant declines were primarily grassland birds, whereas species exhibiting significant increases were those associated with human structures and woody vegetation. Likewise,

Table 9. Changes in predictor landscape metrics [1] on the representative farm core areas 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).

		Core Area					Landscape				
Representative Farm	Metric	Base-line	Agri-culture	% in-crease	Wild-life	% in-crease	Base-line	Agri-culture	% in-crease	Wildlife	% increase
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
	Woody edge (%)	49.0	62.3	27	57.9	18	41.8	75.4	83	72.5	71
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	32	144	12
	Woody edge (%)	61.1	74.2	21	66.4	9	63.9	77.9	22	70.8	11

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

McNicholl (1988), Knopf (1994), and Herkert (1994) reported negative correlations between grassland birds with percent forest cover and conversion and fragmentation of the prairie ecosystem.

Guild Effects

A problem of scale in guild definition was reflected in the fact that none of the landscape variables used for this study were found to predict species richness or relative abundance for birds within the Grassland-field guild at this level of investigation. Although there are relatively fewer birds within this guild, these species also may be responding to biotic factors (i.e., habitat changes) as well as to abiotic factors (i.e., climatic instability) (Zimmerman, 1992) on both a finer as well as a broader scale than was measured. The primary determinant of the presence of birds within the Grassland-field guild could be the depressive effects of woody habitat such as shelterbelts. Therefore, policies implementing shelterbelts on the agricultural landscape, coupled with a reduction in the size of crop fields; increases the relative amounts of woody vegetation and edge habitats (e.g., promoting species richness by favoring Forest-edge/generalist species), potentially causing further declines in the abundance of the Grassland-field guild.

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) was probably limited for Forest-interior birds in landscapes that completely lack extensive tracts of woody habitats (refer to Whitcomb et al., 1976). There were no Forest-interior birds projected to be positively influenced by policies promoting shelterbelts at the farm-level. This was primarily due to the greater edge density values and total edge percentages resulting from each of the shelterbelt scenarios. The classification of species according to their preference for forest interior habitat or avoidance of small patches tends to focus attention at the local scale. However, as Villard et al. (1995) and Wiens (1995) have suggested, processes underlying these phenomena may take place over landscape scales. Villard et al. (1995) further noted that woody patch occupancy by birds tends to be influenced by the landscape context (proximity to other local populations), rather than solely by local characteristics.

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 were not different at the landscape-level than on the core farms. However, an individual farmers' 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 are 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.

Conclusions

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. A process was developed for which wildlife considerations could be integrated into economic and environmental models (Cassidy, 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.

The modeling system provides an initial framework for integrating a wildlife habitat assessment process into agricultural policy analysis. This research demonstrates that alterations to the landscape due to policies promoting the implementation of shelterbelts influences the bird community at the farm- and landscape-level. As a result of this initial effort, land stewardship goals and opportunities for wildlife will hopefully be a more visible alternative within existing 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.

This study investigated the influence of shelterbelt agroforestry policies on the composition of the breeding bird community at the farm-level. 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. 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 are also influenced to some extent by the regional land use and landscape patterns occurring at much larger scales (see Maurer and Villard, 1994; Villard, 1998).

Since past research suggests that the composition of the bird community at the farm-level is influenced by landscape patterns at larger spatial scales, an examination was made of the extent to which breeding bird species

richness and community composition within Breeding Bird Survey route segments (621 hectares on average) were determined by land use and other landscape correlates. The composition of the breeding bird community which results from the implementation of shelterbelt agroforestry policies was projected at the farm-level and for the surrounding landscape. Within this agroecosystem, the composition and distribution patterns of the bird community at the farm- and landscape-level are primarily determined by agricultural land use decisions. Bird distribution patterns are affected directly by crop cultural practices and by the methods employed in managing non-crop areas (such as fence-rows, shelterbelts and other adjacent natural habitat) within these systems.

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