AN ABSTRACT FOR THE THESIS OF

Brian Flock for the Master of Science Degree in Biology presented on

May 29, 2002.

Title: Landscape features associated with greater prairie-chicken lek locations in Kansas

Abstract approved: Elmer J. Finck

I conducted a landscape level investigation of the associations of topography, land cover, and landscape metrics with greater prairie-chicken (*Tympanuchus cupido pinnatus*) lek locations in Kansas. I used Kansas Department of Wildlife and Parks greater prairie-chicken lek data with 1:24000 Digital Elevation Model (DEM) grids to examine the associations of topography with lek versus random locations and traditional versus temporary lek locations. I used discriminant function analysis to develop an overall model of all lek locations combined and for each of 5 physiographic provinces. For lek versus random locations, elevation was a common predictor in all models ($P < 0.001$). For traditional versus temporary leks locations, topography was a poorer predictor ($P < 0.05$) than for lek versus random locations.

Using land cover maps created from satellite imagery, I used discriminant function analysis to model lek versus random locations and traditional versus temporary lek locations. I developed models for all lek locations combined and for each of 4 physiographic provinces within 1.6 km and 4.0 km buffers. For lek versus random locations in the 1.6 km buffer, grassland area was a common predictor ($P < 0.001$) to all models. For traditional versus temporary lek locations, forest area was the predictor for 3

models ($P < 0.01$). The 1.6 km models were better predictors than the 4.0 km models. Land cover area alone was a better predictor than landscape metrics.

I also developed combined models for the 1.6 km buffer land cover, landscape metrics, topography, and 4.0 km buffer land cover and topography. These models showed only slight improvement in accuracy over the general land cover models. I found that lek locations in Kansas were associated with larger blocks of grassland than has been reported previously.

LANDSCAPE FEATURES ASSOCIATED WITH GREATER PRAIRIE-CHICKEN LEK LOCATIONS IN KANSAS

A Thesis

Presented to

The Department of Biological Sciences

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

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by

Brian E. Flock

May 2002

Approved by Major Advisor

Approved by Committee Member

Approved by Committee Member

Approved by Committee Member

Approved by Department Chair

Approved by Dean of Graduate
Studies and Research

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PREFACE

My thesis is the accumulation of two and a half years of research. It all began with a simple idea and grew into a project that I will still be working on long after my thesis is written. What is not presented here are all the ideas that I did not have time to pursue, as well as the problems often associated with research. My thesis is a scaled back version of what I had originally hoped to do. My research was limited mostly by time and funding. My thesis is written in the manuscript style of *Wildlife Monographs*.

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INTRODUCTION

In recent years, landscape ecology has been seen as a method for examining populations of wildlife, and how the configuration of the landscape in which they survive affects the population. Various studies have been conducted on a broad spectrum of wildlife species. Many of these studies have found that landscape scale changes were related to population changes. Woodward et al. (2001) used aerial photos to examine changes in land use along lesser prairie-chicken (*Tympanuchus pallidicinctus*) lek routes in Oklahoma, Texas, and New Mexico,and found that land use changes at the landscape scale were related to population declines. This kind of research requires the creation of land cover and use maps of large areas from remotely sensed images.

Many different methods have been employed to measure land cover for study in landscape scale research, including analysis of aerial photos, digital orthophotos, and satellite imagery. In recent years with a decrease in cost of computers and an increase in their power, satellite imagery has become a more cost-effective means for measuring habitat variables at the landscape level. Researchers have used satellite imagery to evaluate habitat of northern bobwhite (*Colinus virginianus*) (Schairer 1999), wild turkey (*Meleagris gallopavo*) (Glennon and Porter 1999), ruffed grouse (*Bonasa umbellus*) (Palmeirim 1985), lesser prairie-chicken (Cannon et al. 1982), and sage grouse (*Centrocercus urophasianus*) (Homer et al. 1993). These studies found that satellite imagery provided a cost-effective way to measure large areas of habitat for wildlife species and provided a reasonably accurate method for measuring habitat.

Most research on greater prairie-chicken (*T. cupido pinnatus*) have been conducted at small scales within relatively small study areas and based on individual birds. In recent years the greater prairie-chicken has been studied more at the landscape scale. Two recent studies that have examined the greater prairie-chicken at the landscape level are Merrill et al. (1999) and Neimuth (2000). Like most small-scale studies, these studies were conducted in the fringes of the greater prairie-chicken range within highly fragmented landscapes. These studies found that land cover affected greater prairie-chicken lek placement and use by males.

Various researchers have found that historic population fluctuations across the greater prairie-chicken range were related to land use patterns. Stempel and Rodgers (1961) found that the historic peak in greater prairie-chicken populations in Iowa occurred when 69% of the prairie had been converted to cropland. In Missouri, historical peaks occurred when 25-30% of the prairie had been converted to cropland (Bennitt 1939).

Topography is another feature that can affect prairie-chicken populations at the landscape level. For greater prairie-chickens, topography plays a role in sound transmission, which can affect reproduction by either increasing distance that the lek is heard or decreasing the distance and thus decreasing the potential pool of females for mating. A combination of vegetation change and topography can affect the distance that male greater prairie-chickens can be heard (Hamerstrom and Hamerstrom 1960, Sparling 1983). If the lekking habitat needed by greater prairie-chickens is not available within preferred topographic thresholds, then the habitat may not be usable by males for lekking and will cause the population to shift or decline. Anecdotal evidence has often hinted at the types of topography on which greater prairie-chickens will establish leks. In Michigan, researchers noted that greater prairie-chickens often prefer grasslands with small rolling hills, however sharp-tailed grouse (*T. phasianellus*), seem to prefer areas of more sharply-sloping, hilly terrain (Ammann 1957). Horak (1985) found, within his small study area in the Flint Hills of Kansas that the nearest high point to leks was between 1.2 and 1.8 km from the lek. However, the effects of topographic features have not been examined at a large scale.

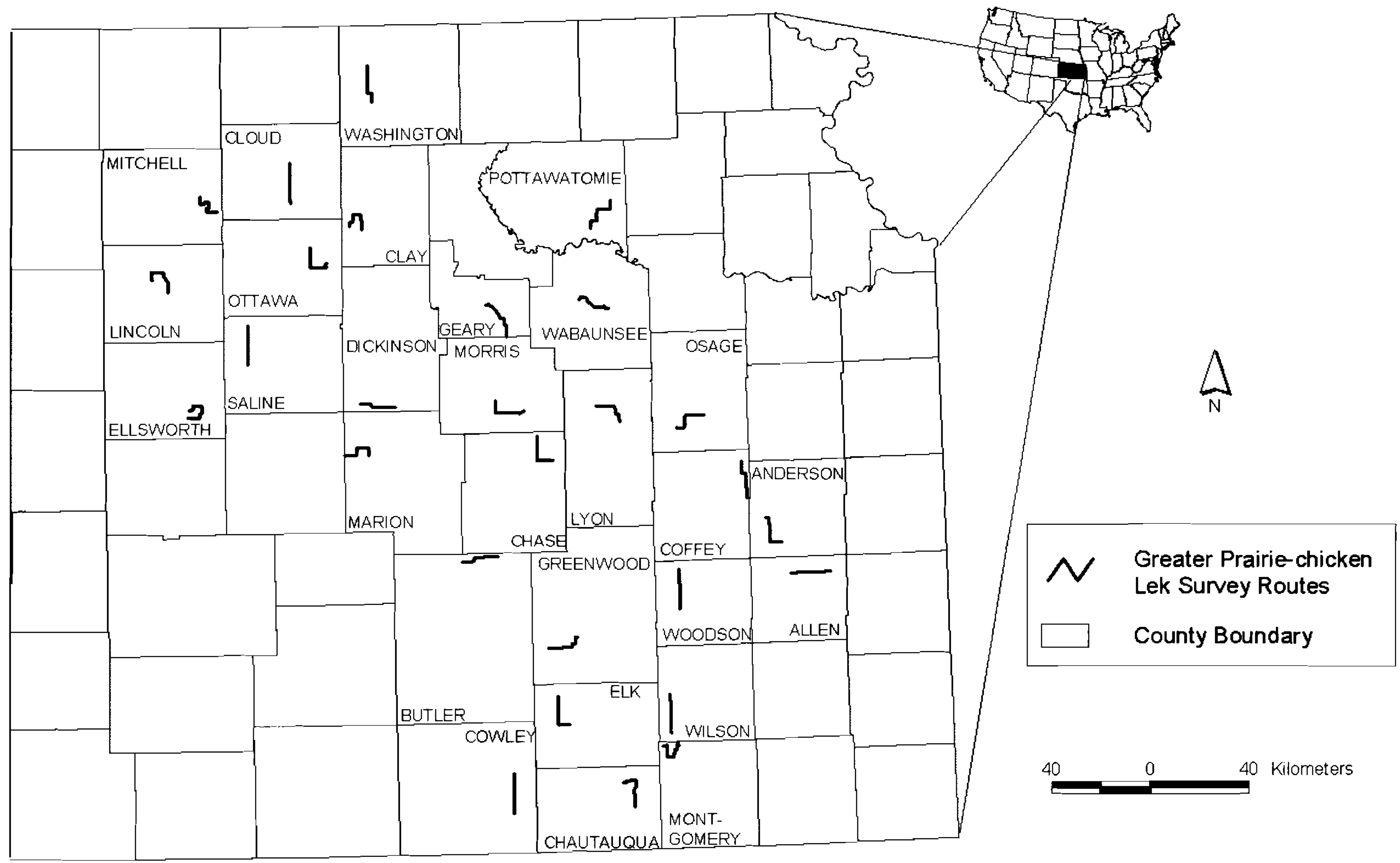
The purposes of my study were to determine 1) whether a difference in land cover and landscape metrics between lek locations and random locations occurs within a 1.6 km buffer, 2) if there is a difference in land cover between lek locations and random locations within a 4.0 km buffer, 3) if there is a difference in land cover and landscape metrics between traditional lek locations and temporary lek locations within a 1.6 km buffer, 4) if there is a difference in land cover and landscape metrics between traditional and temporary lek locations within a 4.0 km buffer, 5) if the lek locations are associated with elevation, slope, or aspect on all areas combined, and within physiographic provinces, and 6) if there are differences in elevation, slope, or aspect between traditional and temporary lek locations.

STUDY AREA

I conducted my research by using the greater prairie-chicken lek survey routes established by Kansas Department of Wildlife in Parks (KDWP) in 28 counties in eastern Kansas (Fig. 1). My study area for the topographic features portion of the study was located within 5 physiographic provinces: the Flint Hills, Glaciated Region, Osage Cuestas, Smoky Hills, and Chautauqua Hills (Fig. 2). Each physiographic province had a varying number of greater prairie-chicken lek survey routes: the Flint Hills contained 9, Glaciated Region 1, Osage Cuestas 7, Smoky Hills 8, and Chautauqua Hills 3. The study area for the land cover and landscape metrics portion of my research was reduced due to satellite image coverage and was located within 4 physiographic provinces: the Flint Hills, Glaciated Region, Osage Cuestas, and Smoky Hills. The greater prairie-chicken lek survey route numbers for these provinces were also reduced due to coverage of satellite images; for the Flint Hills I used 8 routes, Glaciated Region 1, Osage Cuestas 4, and Smoky Hills 5. All physiographic provinces had varying topography ranging from flat to rolling windswept hills (Fig. 3 and Table 1).

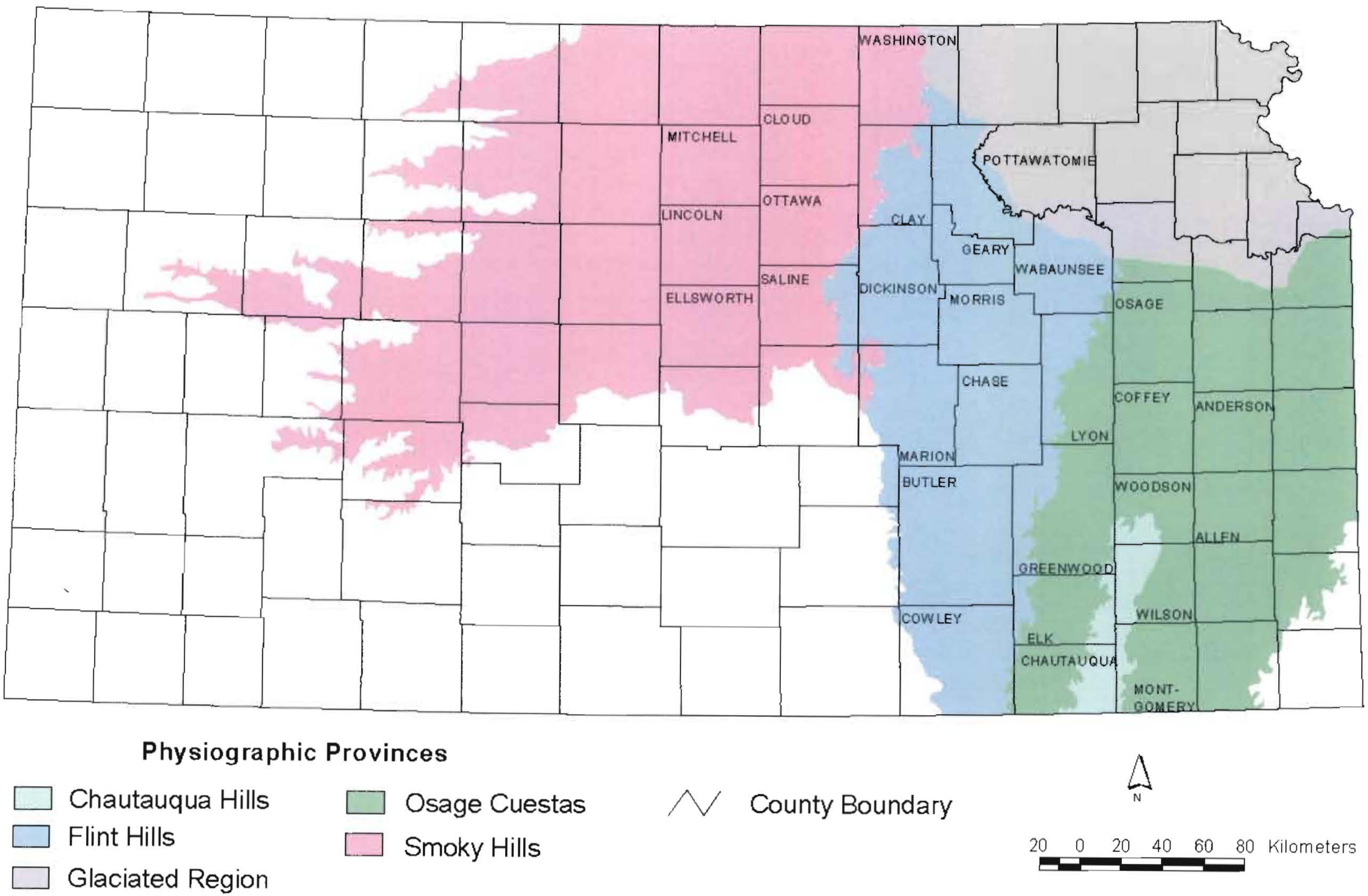
Vegetation of the physiographic provinces varied between regions (Fig. 4 and Table 2). The Flint Hills consisted of large blocks of tallgrass prairie in the uplands and agricultural fields in the floodplains. The Osage Cuestas consisted of large tracts of tallgrass prairie and exotic cool-season grasses intermixed with cropland and forest. The Glaciated Region also consisted of large tracts of tallgrass prairie intermixed with croplands and forest. The Smoky Hills consisted of large blocks of agricultural fields intermixed with blocks of mixed grass prairie in the drier uplands. The Chautauqua Hills

Fig. 1. Kansas Department of Wildlife and Parks 28 greater prairie-chicken lek survey routes (1963-2000).



CLOUD
WASHINGTON
MITCHELL
POTTAWATOMIE
CLAY
OTTAWA
LINCOLN
GEARY
WABAUNSEE
OSAGE
DICKINSON
MORRIS
SALINE
ELLSWORTH
ANDERSON
MARION
LYON
CHASE
COFFEY
GREENWOOD
WOODSON
ALLEN
ELK
BUTLER
COWLEY
WILSON
MONT-
GOMERY
CHAUTAUQUA
N
Greater Prairie-chicken
Lek Survey Routes
County Boundary
40
0
40
Kilometers

Fig. 2. The 5 physiographic provinces that make up the greater prairie-chicken study area.


WASHINGTON
CLOUD
MITCHELL
POTTAWATOMIE
OTTAWA
LINCOLN
CLAY
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WABAUNSEE
SALINE
ELLSWORTH
DICKINSON
MORRIS
OSAGE
CHASE
COFFEY
ANDERSON
LYON
MARION
BUTLER
WOODSON
ALLEN
GREENWOOD
WILSON
COWLEY
ELK
CHAUTAUQUA
MONT-
GOMERY
Physiographic Provinces
Chautauqua Hills
Flint Hills
Glaciated Region
Osage Cuestas
Smoky Hills
County Boundary
N
20 0 20 40 60 80 Kilometers

Fig. 3. A general elevation map depicting locations of the 28 greater prairie-chicken lek survey routes of eastern Kansas.

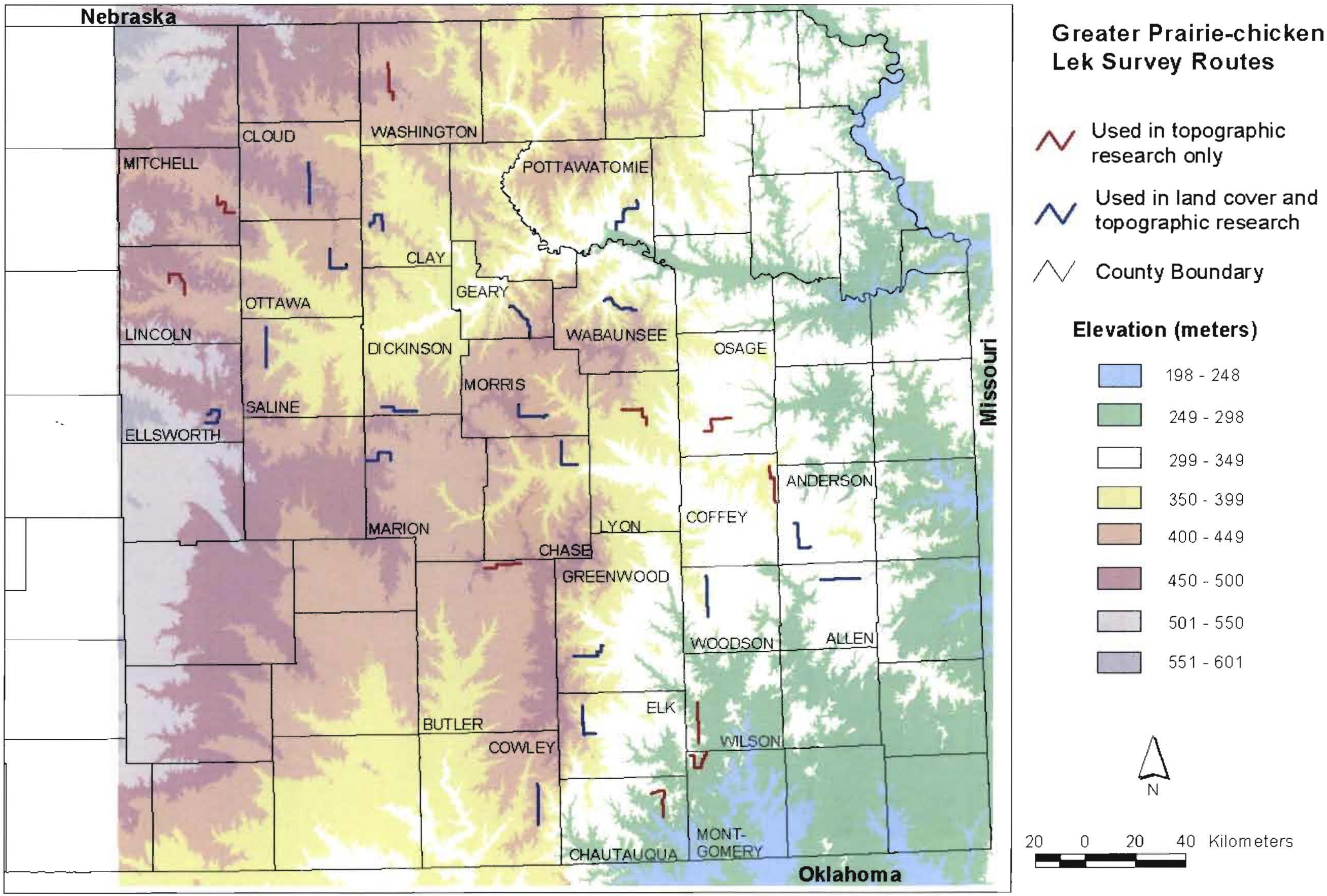

Greater Prairie-chicken
Lek Survey Routes
Used in topographic research only
Used in land cover and topographic research
County Boundary
Elevation (meters)
198 - 248
249 - 298
299 - 349
350 - 399
400 - 449
450 - 500
501 - 550
551 - 601
N
20 0 20 40 Kilometers
Nebraska
Missouri
Oklahoma
MITCHELL
CLOUD
WASHINGTON
POTTAWATOMIE
CLAY
LINCOLN
OTTAWA
GEARY
WABAUNSEE
OSAGE
DICKINSON
MORRIS
SALINE
ELLSWORTH
ANDERSON
COFFEY
MARION
LYON
CHASE
GREENWOOD
WOODSON
ALLEN
ELK
BUTLER
COWLEY
WILSON
MONT-
GOMERY
CHAUTAUQUA

Table 1. Elevation and slope of physiographic provinces summarized from Digital Elevation Models (DEM).

	Elevation				Slope			
Province	Min[1]	Max[2]	Mean	SD[3]	Min	Max	Mean	SD
Chautauqua Hills	215.0	360.0	280.8	24.5	0.0	22.54	2.81	2.41
Flint Hills	284.0	510.0	405.1	33.3	0.0	29.91	2.29	1.98
Glaciated Region	217.0	475.0	338.9	49.0	0.0	31.06	3.09	2.18
Osage Cuestas	204.0	443.0	306.1	33.3	0.0	26.43	1.98	1.68
Smoky Hills	348.0	601.0	458.9	45.8	0.0	24.11	2.05	1.68

[1] Minimum
[2] Maximum
[3] Standard Deviation

Fig. 4. Vegetation map of eastern Kansas adapted from Kansas GAP analysis data with locations of greater prairie-chicken lek survey routes.

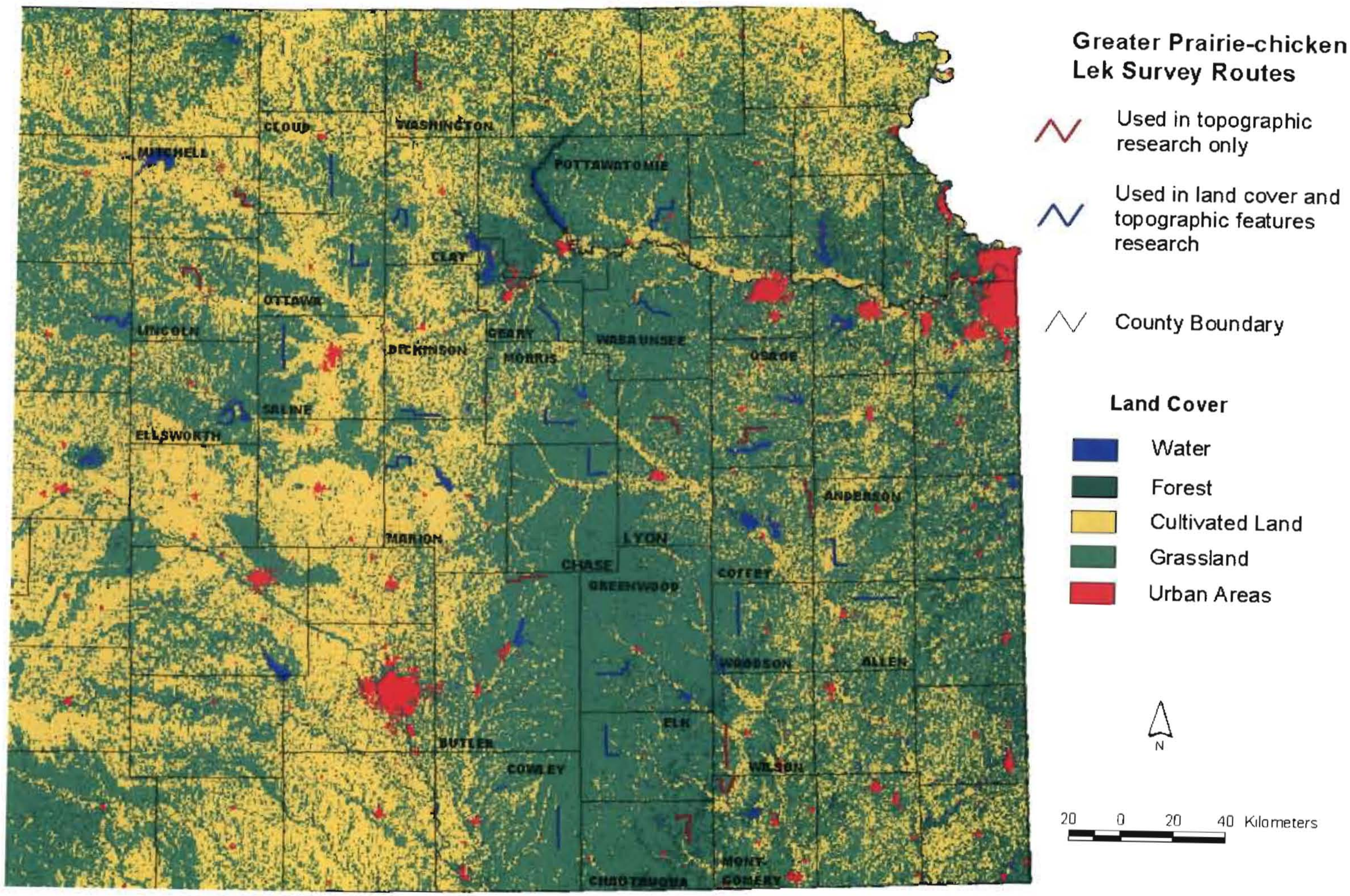

Greater Prairie-chicken Lek Survey Routes
Used in topographic research only
Used in land cover and topographic features research
County Boundary
Land Cover
Water
Forest
Cultivated Land
Grassland
Urban Areas
N
20 0 20 40 Kilometers
CLOUD
WASHINGTON
MITCHELL
POTTAWATOMIE
CLAY
OTTAWA
LINCOLN
GEARY
WABAUNSEE
DICKINSON
MORRIS
OSAGE
SALINE
ELLSWORTH
ANDERSON
MARION
LYON
CHASE
COFFEY
GREENWOOD
WOODSON
ALLEN
ELK
BUTLER
COWLEY
WILSON
MONT-
GOMERY
CHAUTAUQUA

Table 2. Land cover (ha) summarized from Kansas GAP by physiographic provinces.

Province	Forest	Grasssland	Cropland	Urban Areas	Water
Chautauqua Hills	623,206	1,147,835	385,112	10,869	28,099
Flint Hills	2,250,359	14,952,727	7,931,939	212,467	350,522
Glaciated Region	3,559,124	7,151,516	7,849,563	555,148	268,885
Osage Cuestas	5,250,015	15,845,074	8,372,905	723,610	518,406
Smoky Hills	3,064,332	21,155,519	24,807,687	198,102	315,428

consisted of tallgrass prairie intermixed with post oak (*Quercus stellata*) and blackjack oak (Q. *marilandica*) forest and cropland.

METHODS

Lek Survey Methods

I used KDWP greater prairie-chicken lek survey route data from 1963 to 2000 to examine the association of landscape features with lek locations. The greater prairie-chicken lek surveys followed a 16.1 km route in each of the selected counties, and were conducted annually by KDWP employees between 20 March and 20 April. Each survey began 40 minutes before sunrise with the observer stopping once every 1.6 kilometers to listen for booming males within a radius of 1.6 km. Once the initial survey was finished the observer retraces the route and attempted to flush birds from leks noted during the listening phase (Applegate and Horak 1999). Leks were classified as having ≥ 2 booming males present during the flush count (Applegate and Horak 1999). Once the lek was located and flushed the observer used 1:24,000 black and white aerial photos to locate and map the location of the lek onto a ~1:64,000 section map of the survey route.

I obtained county public land survey system (PLSS) layers, Topologically Integrated Geographic Encoding and Referencing (TIGER) line files, digital elevation models (DEM), and digital orthophotos (DOQ) from the Kansas Geographic Information System Initiative's Data Access and Support Center (DASC) in their native coordinate system. Using ArcInfo 8.1 (Environmental Systems Research Insititue, Inc. Redlands, California), I reprojected the PLSS and TIGER line files from their native coordinate system to UTM , Zone 14, with NAD 83 datum.

I digitized the lek location and route data in ArcView 3.2 (Environmental Systems Research Insititue, Inc. Redlands, CA) on-screen. I used PLSS layer and TIGER line files overlain onto DOQs to guide my placement of lek locations from the base maps obtained from KDWP. Lek points were digitized on-screen by route at 1:60,000 scale. Each lek location layer included the lek identification assigned in the field (A, B, C, etc.).

To help classify lek locations as traditional or temporary when digitizing the locations I considered whether the lek was the same lek from year-to-year or was a different lek. I considered a lek the same if it did not move more than 1,000 m from one year to the next. I used 1,000 m for annual lek movement because of map inaccuracies made by observers and digitizing. Also, I felt that lek movements up to 1,000 m would be plausible due to the large tracts of grassland within the study regions I also considered a lek to be the same lek if it was not located within 1,000 m for several years, but was then located close to or at the original location on a given year. I considered a lek to have changed from one year to the next when the movement of that lek was >1,000 m or if it was located where another lek had been the year before. Often this was a small satellite lek located a short distance from the larger more permanent lek. The leks were then renamed (A, B, C, etc.) accordingly.

Topographic Model

To examine topographic features, I used all 28 routes and their locations from 1963 to 2000 with 1:24,000 DEMs. Using ArcInfo 8.1, I reprojected the DEMs from their native coordinate system to UTM, Zone 14, and a datum of NAD 83. After reprojecting the DEM, I used the map calculator in the ArcView extension Spatial Analyst 2.0 (Environmental Systems Research Instititue, Inc. Redlands, California) to convert the Z value (elevation) of the DEMs from feet to meters. I also used Spatial Analyst to join the DEMs together. I then used Spatial Analyst to calculate elevation, slope, and aspect from the DEMs (Figs. 5, 6, 7) .

To compare known lek locations with random locations, I created a 20 km buffer around each of the 28 survey areas. Using a script in ArcView similar to Desanty et al. (2001), I generated random locations within each 20 km buffer. The number of random locations generated was equal to the number of lek locations within each survey area.

Land Cover and Landscape Metrics Model

Satellite Image Classification.—I obtained Landsat Thematic Mapper (TM) images for 1984, 1992, and 2000 from the U.S. Geological Survey Earth Resources Observation Systems (EROS) Data Center, Sioux Falls, South Dakota. Two Kansas scenes were obtained: path/row 28/33 and 27/34 (Fig. 8). Three images were obtained for each year and each scene: one for late spring (late April or early May), one for summer (July or August), and one for September.

I used the extension Image Analysis 1.1 (Environmental Systems Research Instititue, Inc. Redlands, California) for ArcView 3.2 to import each satellite image into an ERDAS Imagine file (ERDAS, Inc., Atlanta, Georgia), which stacks or layers all bands from the satellite image into one file. I then used 20 DOQs scattered around the image to aid in rectifying the satellite images to an accuracy of < 15 m (< 0.5 pixel).

Once all images for a year were rectified, I removed bands 1, 2, and 6 from each image by using the Subset command in Image Analysis. This left me with 4 bands (3, 4, 5, and 7) for each image. These bands were used because they have been found to more accurately distinguish vegetation (Egbert et al. 1995). I then stacked the new image files into a single 12-band file containing 4 bands from each season, April/May, July/August, and September, similar to Price et al. (1997).

Fig. 5. An example of elevation created from Digital Elevation Model (DEM) in the ArcView extension Spatial Analyst 2.0.

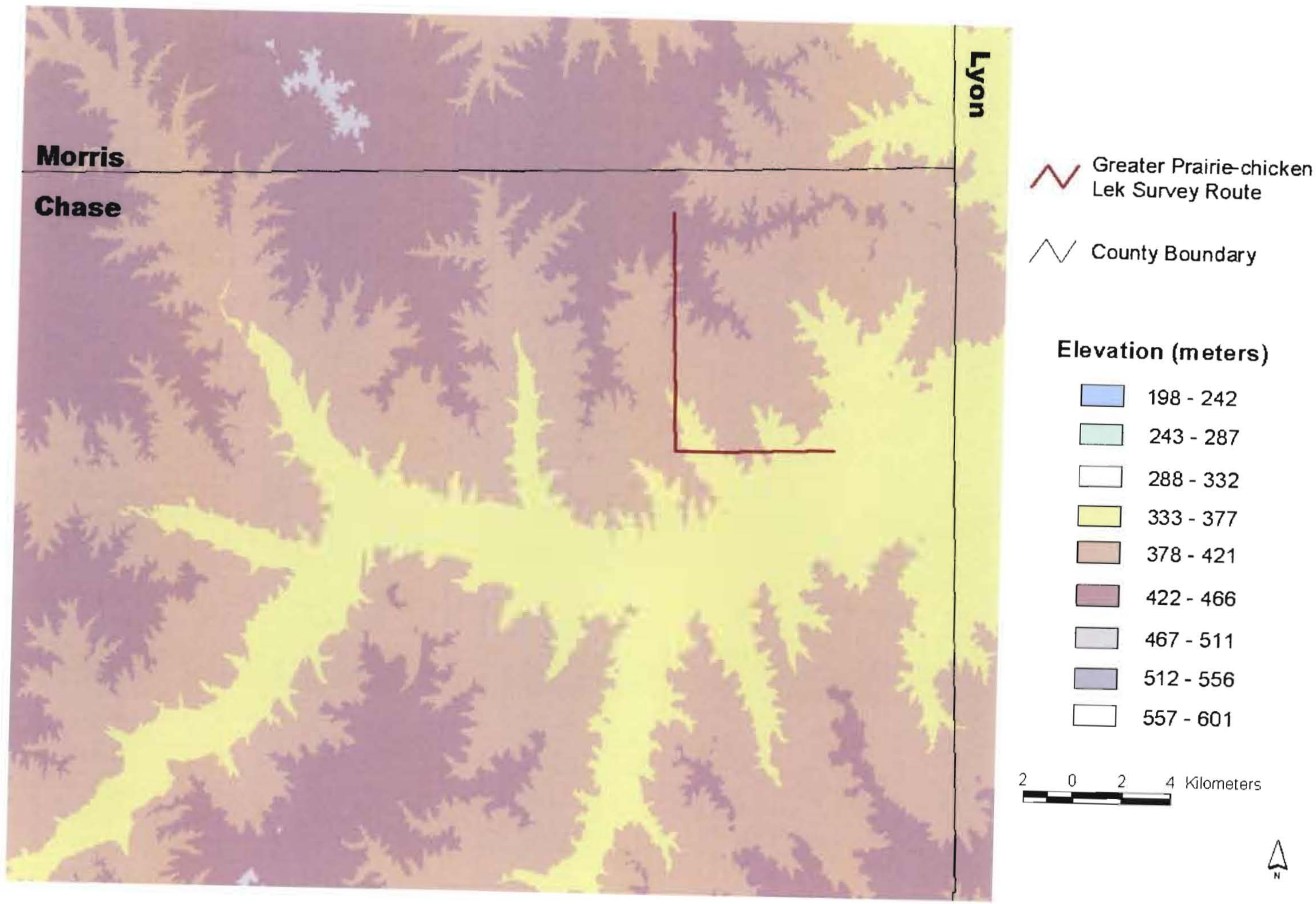

Morris
Chase
Lyon
Greater Prairie-chicken Lek Survey Route
County Boundary
Elevation (meters)
198 - 242
243 - 287
288 - 332
333 - 377
378 - 421
422 - 466
467 - 511
512 - 556
557 - 601
2 0 2 4 Kilometers
N

Fig. 6. An example of slope calculated from Digital Elevation Model (DEM) in the ArcView extension Spatial Analyst 2.0.

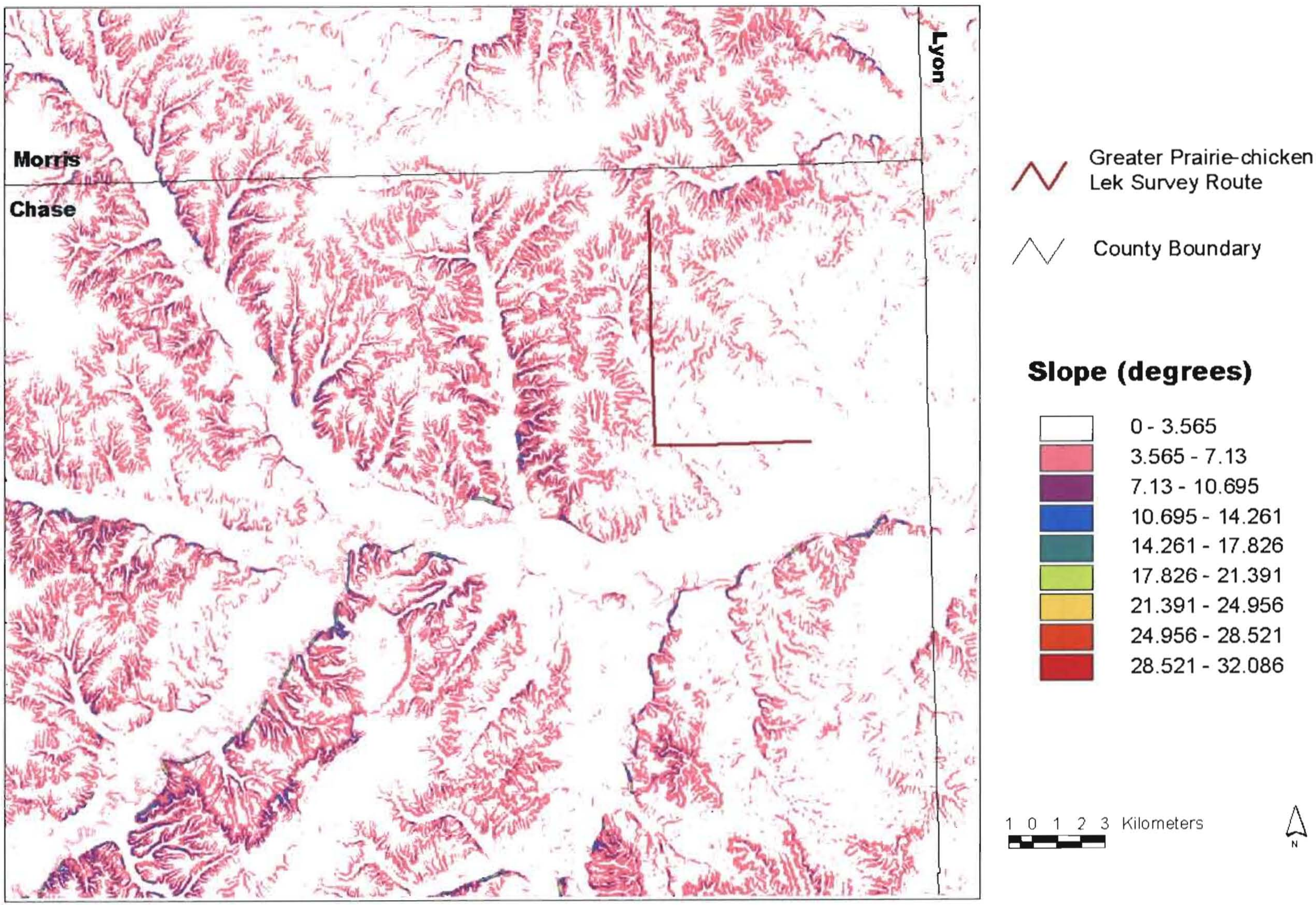

Morris
Chase
Lyon
Greater Prairie-chicken Lek Survey Route
County Boundary
Slope (degrees)
0 - 3.565
3.565 - 7.13
7.13 - 10.695
10.695 - 14.261
14.261 - 17.826
17.826 - 21.391
21.391 - 24.956
24.956 - 28.521
28.521 - 32.086
1 0 1 2 3 Kilometers
N

Fig. 7. An example of aspect calculated from Digital Elevation Models (DEM) in the ArcView extension Spatial Analyst 2.0.

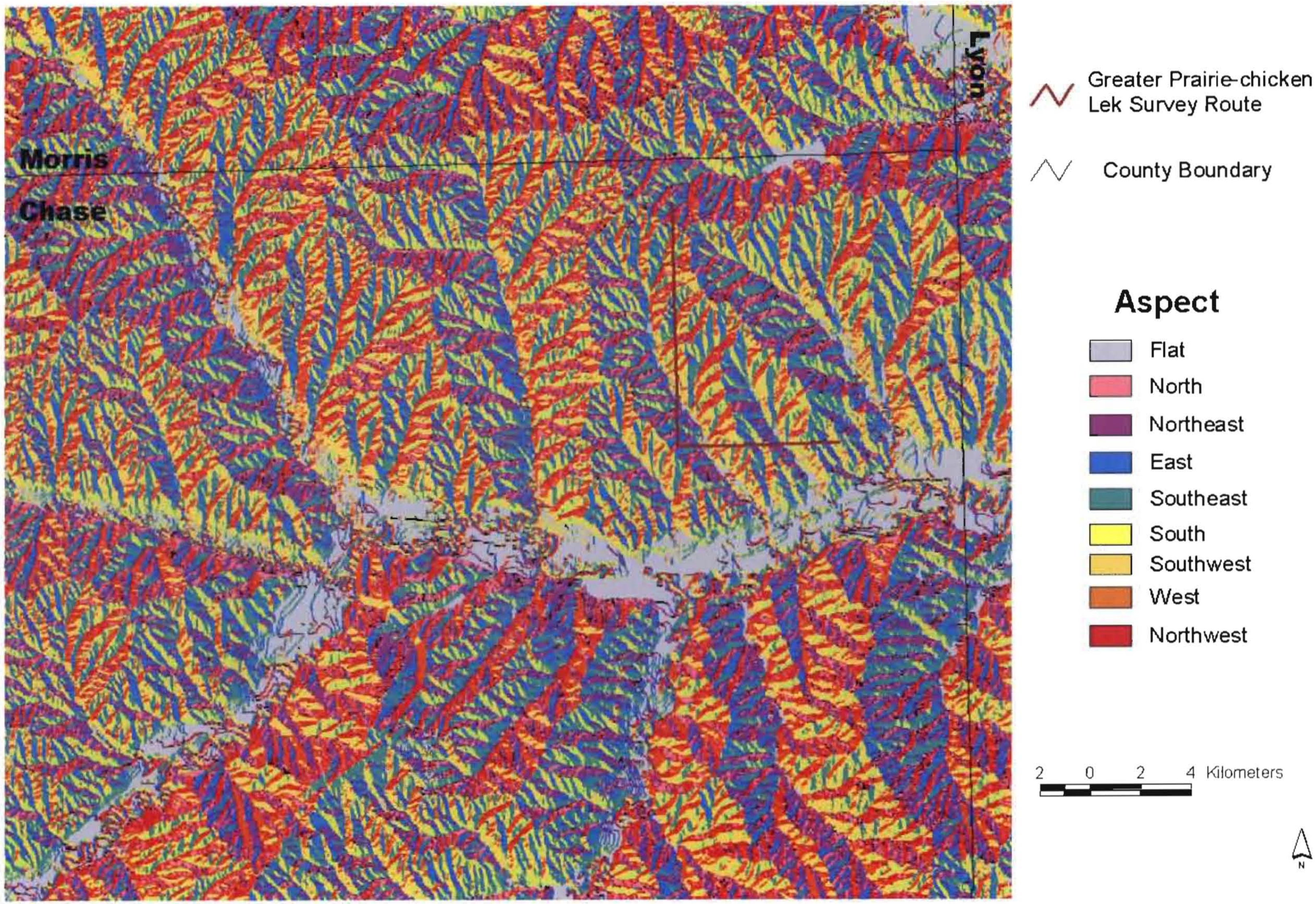
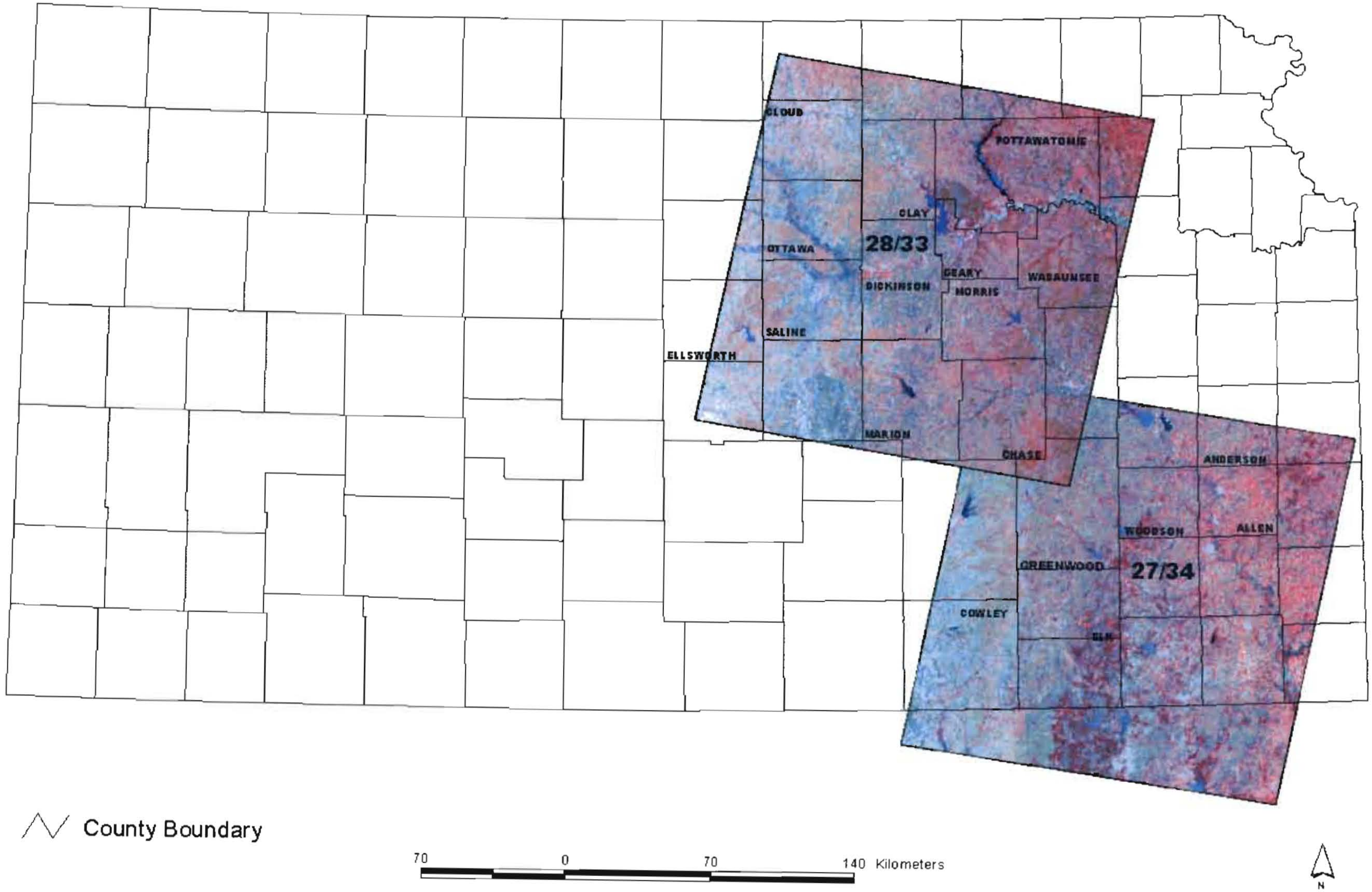

Lyon
Morris
Chase
Greater Prairie-chicken Lek Survey Route
County Boundary
Aspect
Flat
North
Northeast
East
Southeast
South
Southwest
West
Northwest
2 0 2 4 Kilometers
N

Fig. 8. Locations of the two Landsat TM scenes used to develop the land cover map.


CLOUD
POTTAWATOMIE
CLAY
28/33
OTTAWA
GEARY
WABAUNSEE
DICKINSON
MORRIS
SALINE
ELLSWORTH
MARION
CHASE
ANDERSON
WOODSON
ALLEN
GREENWOOD
27/34
COWLEY
ELK
County Boundary
70
0
70
140 Kilometers
N

I digitized on-screen in ArcView, all urban and developed lands with the satellite image as the base map. I also digitized on-screen any areas of cloud cover and cloud shadows for classification at a later time (Lillesand et al. 1998). I removed the urban/developed lands and cloud cover from the physiographic provinces layer (Lillesand et al. 1998) and then used the new layer as a mask to subset the 12 band images for each year and path/row. This gave me an image of each physiographic province with 12 bands minus urban areas, cloud cover, and cloud shadows.

I used an unsupervised classification with the Categorize command in Image Analysis to group the subset of physiographic province pixels into 100 clusters. After the initial classification, the image was grouped into 1 of 6 land cover classes: residential/developed lands (urban), rangeland/hayfield/Conservation Reserve Program (CRP) (grassland), agricultural fields (cropland), forest, open water, and other (sand bars). Any clusters that I felt were confused (i.e., cropland that was actually grassland) were grouped into a seventh cluster labeled confusion. I then used these confused clusters as a mask and began cluster busting (Jensen et al. 1987) until the number of pixels in the known confusion area was less than 23 (2 ha).

Cloud cover and cloud shadows were then classified by using the unsupervised classification technique as described above. The bands from the cloud free images were used to classify the cloud cover areas. The number of bands for each cloud cover area varied from 8 to 6 bands, depending on the images that were cloud free. If cloud cover from one image date overlapped with cloud cover of another image date, the overlapping cloud area was removed and a single date of imagery, which included bands 1 through 5 and 7, was used.

I used Image Analysis and Spatial Analyst 2.0 (Environmental Systems Research Institue, Inc. Redlands, California) extension for ArcView to create a mosaic and combine the broken classified images back into one image with 5 classes. I converted the urban coverage into a grid in Spatial Analyst. I used the Combine command in Spatial Analyst to add the urban grid with the 5 other land cover classes.

I used the Clean functions in Spatial Analyst to remove possible misclassified cells and used the Majority Filter command to remove single misclassified cells. I then used the Region Group command to group like cells together. This was followed by the Extract By Count command to group regions < 23 cells (2 ha) into a mask. Then I used the Nibble command to replace the areas < 2 ha with the values of neighboring cells.

A combination of DOQs and ground truthing was used to determine the overall accuracy of each yearly classification. No ground truthing was done for 1984. The classified vegetation map for 1992 and 2000 had accuracies of 87.1% and 81.0%, respectively (Appendices 1 and 2).

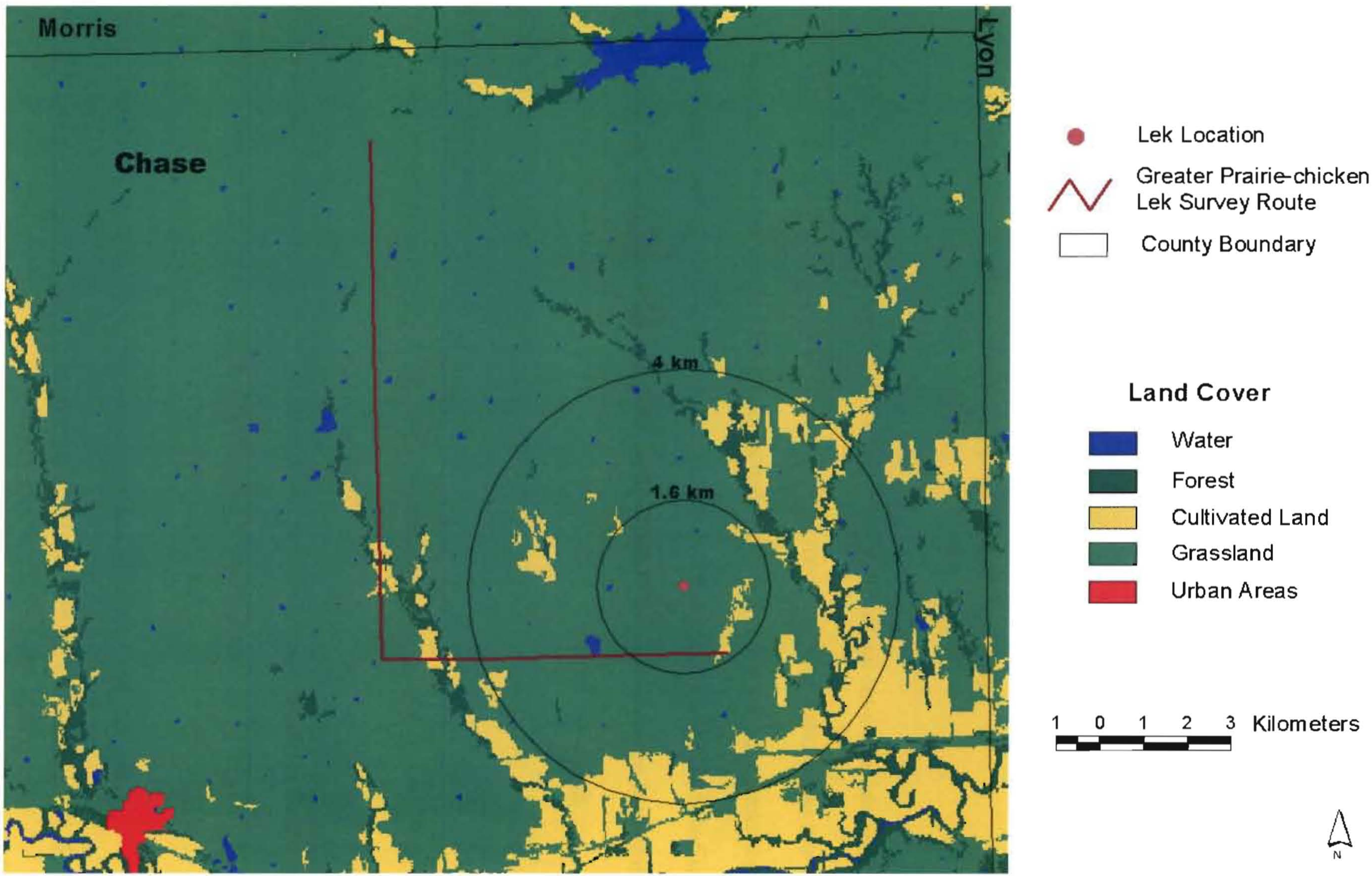
Lek Land Cover.—To examine land cover associations with greater prairie-chicken leks I used 18 of the 28 lek survey routes, which were located ≥ 8 km from the edge of the classified image. For each land cover class and year, I used 3 years of lek data within ± 2 years of images. For example for the 1984 land cover map for some of the routes I used 1983, 1984, and 1985 lek data. However, for other routes this may have been 1982, 1983, and 1986 due to surveys not being run in a given year. I used the Buffer Theme Builder ArcView extension (O'Malley 1998) to create circular buffers for each lek location at 2 radii: 1.6 km (800 ha) and 4.0 km (1,001 ha) (Fig. 9). I used 1.6 km for leks because, during April, males have been found to move up to 1,327 m per day

(Robel et al. 1970, Drobney and Sparrowe 1977). Merrill et al. (1999) used this distance for a similar study in Minnesota. The 4.0 km buffer was used as a general landscape.

Lek Landscape Metrics.—To calculate the landscape metrics I used the 1.6 km buffers created for the land cover analysis and Arc/Info 8.1 to convert each land cover grid to a polygon coverage. I then used each lek and random point buffer as a template to clip the polygon land cover map into individual clipped coverages. I used the ArcView extension Patch Analyst (Elkie et al. 1999) to calculate 11 landscape metrics at the land cover class level: number of patches, mean patch size, median patch size, total edge per patch, edge density for each patch, mean patch edge, mean perimeter-area ratio, mean shape index, area-weighted mean shape index, mean fractal dimension, and area-weighted mean patch fractal dimension.

Mean patch size was the average of all patches within a given cover class (Elkie et al. 1999). Median patch size was calculated as the middle patch size or the patch within the 50^{th} percentile within that class (Elkie et al. 1999). Total edge is the total perimeter of all patches within a given class (Elkie et al. 1999). Edge density for each class is the amount of edge divided by the landscape area (Elkie et al. 1999). Mean patch edge is the average amount of edge per patch. Mean perimeter-area ratio is a measure of shape complexity for each patch (Elkie et al. 1999). Mean shape index (MSI) is another measure of shape complexity where MSI = 1 when all patches are circular (McGarigal and Marks 1995, Elkie et al. 1999). MSI was the method used by Merrill et al. (1999) to measure patch shape complexity. I calculated MSI for comparison with their study. Area-weighted mean shape index applies a weighting based on each patch size to the shape index for each patch. Mean patch fractal dimension is another method

Fig. 9. An example of the 2 buffers used around each lek location to summarize land cover and landscape metrics.


Morris
Chase
Lyon
4 km
1.6 km
Lek Location
Greater Prairie-chicken
Lek Survey Route
County Boundary
Land Cover
Water
Forest
Cultivated Land
Grassland
Urban Areas
1 0 1 2 3 Kilometers
N

for calculating shape complexity. Mean patch fractal dimension equals 1 with simple perimeters and approaches 2 when shapes are more complex (McGarigal and Marks 1995, Elkie et al. 1999). Area-weighted mean patch fractal dimension calculates the mean patch fractal dimension with the addition of each patch area weighting applied to the patch. This allows for the complexity of the patch shape to be examined independent of the size of the patch (McGarigal and Marks 1995, Elkie et al. 1999).

Combined Model

I created a model that used all of the variables from the land cover, landscape metrics, and topographic models, to see if a combined model of these features was more accurate at modeling lek versus random points and traditional versus temporary leks than the individual models. For lek and random locations I used the points and 1.6 km buffers from the land cover and landscape metrics model. Random locations from the land cover and landscape metrics model were summarized with the elevation and slope grids calculated from the DEMs for the topographic model.

Statistical Analyses

I used a histogram of the lek frequencies to determine the break between traditional and temporary (satellite) leks. I used SPSS 10.0 (SPSS Inc. Chicago, Illinois) to calculate all statistics and an $\alpha \leq 0.05$ to reject all null hypotheses. Model accuracy as report in the results was the probability of the model correctly classify a location as lek, random, traditional, or temporary.

I tested lek locations from year to year for autocorrelation and found none. Therefore, I made 3 assumptions before running the discriminant function analyses: 1) all lek locations were independent of each other and were able to be within any distance from another lek location, 2) year to year lek locations were independent of the preceding year's location because a lek location could move to any another location from year to year, 3) all KDWP lek survey routes were subsamples of possible greater prairie-chicken habitat and therefore had no effect on lek locations. A fourth assumption made when dealing with the land cover and landscape metrics associations was that land cover at the landscape level changed little within 2 years on either side of the date of the satellite images used in classifications.

Topographic Model.—I used stepwise discriminant function analysis to determine if elevation, slope, and aspect could be used to distinguish lek locations from random points for all routes combined and by geographic provinces. I also used stepwise discriminant function analysis to compare traditional versus temporary leks with respect to elevation, slope, and aspect for all routes combined and by physiographic provinces. I used one-way ANOVA to test equality of group means for topographic features between lek versus random locations and traditional versus temporary leks.

Land Cover Model.—I used stepwise discriminant function analysis to determine if the 6 land cover classes extracted from the satellite images could be used to model lek locations and random locations within the 1.6 km and 4.0 km buffers. Stepwise discriminant function analysis was used to model lek locations and random locations within each buffer for 1984, 1992, and 2000 to see if the model varied among years. I also modeled each year at the classified landscape level as well as at each physiographic province level. I used stepwise discriminant function analysis to model lek locations and random locations by land cover class for all years combined at the region level as well as for each physiographic province. I used one-way ANOVA to test equality of group means for topographic features between lek locations versus random locations.

Stepwise discriminant function analysis also was used to determine if the 6 land cover classes could predict traditional and temporary leks for each year in the whole region and in each physiographic province. I modeled all years combined at the regional and physiographic province levels and tested equality of group means for topographic features between traditional versus temporary lek locations with one-way ANOVA.

Combined Model.—For the combined model, I used land cover classes, landscape metrics, and topographic features found to be significant predictors in the other models. I used stepwise discriminant function analysis to determine if lek locations and random locations could be more accurately predicted with the combined model at the classified level and at the physiographic province level. I used discriminant function analysis to determine if these same features more accurately could model temporary versus traditional lek locations.

RESULTS

Topographic Model

All Lek Locations Versus Random Locations.—I found 3,891 lek locations from 1963 to 2000 within the 28 survey areas. I generated a total of 3,891 random locations within the 20 km buffers. The overall model was 55.1 % accurate (Wilkes' $\lambda = 0.97$, $F_{2,7779} = 119.094$, $P < 0.001$). The discriminant function correctly classified lek locations 56.5% of the time, and random locations were misclassified 46.3% of the time as lek locations. For the overall model 2 of the 3 topographic features were predictors of lek versus random points: elevation and slope. Lek locations had a significantly higher elevation ($F_{1,7780} = 223.610$, $P < 0.001$) and flatter slope ($F_{1,7780} = 10.545$, $P = 0.001$) than random locations (Table 3).

I also examined the predictability of aspect, slope, and elevation by the 5 physiographic provinces. First, I examined the Flint Hills, which had 1840 lek locations and 1840 random locations. The overall model for the Flint Hills was 59.9% accurate (Wilkes' $\lambda = 0.911$, $F_{2,3677} = 180.622$, $P < 0.001$). The discriminant function analysis classified lek locations accurately 68.1% of the time and misclassified random locations 48.3% of the time as lek locations. The discriminant function analysis found elevation and slope to be predictors. Lek locations had significantly higher elevation ($F_{1,3678} = 354.727$, $P < 0.001$) and a significantly flatter slope ($F_{1,3678} = 28.792$, $P < 0.001$) than did random locations (Table 3).

I found 672 lek locations and generated 672 random locations for the Smoky Hills. The model had an overall accuracy of 64.9% (Wilkes' $\lambda = 0.885$, $F_{2,1341} = 87.31$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 64.4% of the time and misclassified random locations as leks 34.7% of the time. The discriminant function analysis for Smoky Hills also found elevation and slope to be predictors. Lek locations again had a significantly higher elevation ($F_{1,1342}$ = 124.219, $P < 0.001$) than random locations, but leks had a significantly steeper slope ($F_{1,1342}$ = 53.376, $P < 0.001$) than random locations (Table 3).

I found 1033 lek locations and generated 1033 random locations for the Osage Cuestas. The overall model accuracy was 61.5% (Wilkes' λ = 0.966, $F_{2,2063}$ = 35.896, P <0.001). The Osage Cuestas model predicted lek locations 60.5% of the time, but misclassified random locations as lek locations 37.4% of the time. The discriminant function analysis found elevation and slope to be predictors of lek locations. Lek locations had significantly higher elevation ($F_{1,2064}$ = 38.784, $P < 0.001$) and flatter slope ($F_{1,2064}$ = 25.236, $P < 0.001$) than random locations (Table 3).

I found 92 lek locations and generated 92 random locations for the Chautauqua Hills. The model had an overall accuracy of 82.6% (Wilkes' λ = 0.753, $F_{2,181}$ = 29.688, $P < 0.001$) . The discriminant function correctly classified lek locations 95.7% of the time and misclassified random locations 30.4% of the time. Elevation and slope again were found to be predictors of lek locations, with significantly higher elevations ($F_{1,181}$ = 51.627, P < 0.001) and a flatter slope ($F_{1,181}$ = 10.212, $P < 0.001$) than random locations (Table 3).

Within the Glaciated Region I found 254 lek locations and generated 254 random locations. The model had an overall accuracy of 70.7% (Wilkes' λ = 0.701, $F_{1,506}$ = 216.123, $P < 0.001$). The discriminant function analysis correctly identified lek locations 71.3 % of the time and misclassified random locations as lek locations 29.9% of the time.

Elevation was the only predictor for lek locations versus random locations in the Glaciated Region. Leks had significantly higher elevation ($F_{1,506}$ = 216.123, P < 0.001) than random locations (Table 3).

Traditional Leks Versus Temporary Leks.—I found 3012 traditional leks and 878 temporary leks. When examining the traditional versus temporary leks, the overall model for all routes combined was 59.7% accurate (Wilkes' $\lambda = 0.999$, $F_{1,3888} = 4.615$, $P = 0.034$). The discriminant function analysis correctly classified traditional leks 66.5% of the time and misclassified temporary lek locations as traditional lek locations 63.4% of the time. The only predictor of traditional lek locations for all routes was slope. Traditional lek locations had significantly flatter slope ($F_{1,3888} = 4.614$, $P = 0.032$) than did temporary lek locations (Table 4).

I also examined traditional versus temporary lek locations at the physiographic province level. The Flint Hills had 1440 traditional lek locations and 399 temporary lek locations. The model for the Flint Hills had an overall accuracy of 49.2% (Wilkes' $\lambda = 0.998$, $F_{1,1837} = 4.173$, $P = 0.041$). The discriminant function analysis was able to accurately predicted temporary leks 59.6% of the time and misclassified traditional leks as temporary 46.3% of the time. The only predictor of traditional lek locations versus temporary lek locations was elevation. Temporary lek locations had a significantly higher elevation ($F_{1,1837} = 4.173$, $P = 0.041$) than did traditional lek locations (Table 4).

The Smoky Hills had 508 traditional lek locations and 164 temporary lek locations. The Smoky Hills model had an overall accuracy of 56.3% (Wilkes' $\lambda = 0.987$, $F_{1,670} = 8.549$, $P = 0.004$). The discriminant function analysis predicted temporary lek locations 57.3 % of the time and misclassified traditional lek locations as temporary lek

Table 3. Comparison of slope, elevation, and aspect of all lek locations versus random locations.

		Traditional Leks					Temporary Leks				
		n	Min[a]	Max[b]	Mean	SD[c]	n	Min	Max	Mean	SD
Overall Combined	Slope	3012	0.000	14.484	2.000	1.639	878	0.000	10.607	2.135	1.681
	Elevation	3012	299.000	509.000	404.877	50.940	878	297.000	507.000	404.769	51.515
	Aspect[1]	3012	-1.000	355.601	159.153	105.084	878	-1.000	356.633	160.523	96.078
Chautauqua Hills	Slope	69	0.000	5.151	1.949	0.957	23	0.755	3.931	1.836	0.955
	Elevation	69	299.000	319.000	308.667	5.580	23	297.000	323.000	304.870	7.226
	Aspect[1]	69	-1.000	315.000	157.615	80.903	23	101.300	353.660	234.272	74.289
Flint Hills	Slope	1440	0.000	11.727	1.900	1.643	399	0.000	10.607	1.865	1.525
	Elevation	1440	368.000	479.000	429.873	26.318	399	363.000	477.000	423.932	27.019
	Aspect[1]	1440	-1.000	355.601	160.015	101.516	399	-1.000	358.264	167.186	104.398

continued

Table 3. continued.

		All Lek Locations					Random Locations				
		n	Min[a]	Max[b]	Mean	SD[c]	n	Min	Max	Mean	SD
Glaciated Region	Slope	254	0.338	7.653	3.152	1.410	254	0.000	12.814	2.990	1.937
	Elevation	254	331.000	408.000	357.492	22.429	254	281.000	426.000	338.898	32.723
	Aspect[1]	254	0.000	348.690	163.621	92.998	254	-1.000	354.806	156.953	98.911
Osage Cuestas	Slope	1033	0.000	14.484	1.493	1.410	1033	0.000	19.181	1.826	1.597
	Elevation	1033	308.000	436.000	343.287	19.692	1033	273.000	498.000	335.132	37.196
	Aspect[1]	1033	-1.000	357.138	155.467	106.386	1033	-1.000	357.138	155.467	106.386
Smoky Hills	Slope	672	0.000	7.973	2.823	1.750	672	0.000	11.276	2.132	1.714
	Elevation	672	403.000	509.000	453.503	27.660	672	360.000	549.000	433.982	36.005
	Aspect[1]	672	-1.000	352.875	164.409	102.245	672	-1.000	357.879	161.267	105.511

[1] An aspect of –1.000 is equal to a flat surface.
[a] Minimum

[b] Maximum

[c] Standard Deviation

locations 44.1% of the time. The only predictor for the Smoky Hills was elevation. In the Smoky Hills, traditional lek locations had a significantly higher elevation ($F_{1,670} = 8.549$, $P = 0.004$) than did temporary lek locations (Table 4).

The Osage Cuestas had 794 traditional leks locations and 239 temporary lek locations. The model for the Osage Cuestas had an overall accuracy of 56.1% (Wilkes' $\lambda = 0.994$, $F_{1,1031} = 6.517$, $P = 0.011$). The discriminant function analysis correctly classified traditional lek locations 56.5% of the time and misclassified temporary lek locations as traditional lek locations 45.2% of the time. Elevation was the only predictor of traditional versus temporary lek locations for the Osage Cuestas. Temporary lek locations had a significantly higher elevation ($F_{1,1031} = 6.517$, $P = 0.011$) than did traditional lek locations (Table 4).

The Chautauqua Hills had 69 traditional lek locations and 23 temporary lek locations. The model had an overall accuracy of 71.7 % (Wilkes' $\lambda = 0.769$, $F_{2,89} = 13.339$, $P < 0.001$). The discriminant function analysis correctly classified temporary lek locations 73.9% of the time and misclassified traditional lek locations as temporary lek locations 29.0% of the time. Two topographic features were identified as predictors of traditional lek locations within the Chautauqua Hills: aspect and elevation. Traditional lek locations had a significantly higher elevation ($F_{1,90} = 6.854$, $P = 0.01$) and a more southerly aspect ($F_{1,90} = 16.105$, $P < 0.001$) than did temporary lek locations (Table 4).

The Glaciated Region had 201 traditional lek locations and 53 temporary lek locations. The model for this region had an overall accuracy of 67.7% (Wilkes' $\lambda =$ 0.946, $F_{1,252} = 14.396$, $P < 0.001$). The discriminant function analysis predicted traditional lek locations correctly 69.2% of the time and misclassified temporary lek locations as traditional lek locations 37.3% of the time. Only elevation was found to be a predictor of traditional versus temporary lek locations in the Glaciated Region. Traditional lek locations had a significantly higher elevation ($F_{1,252}$ = 14.396, P < 0.001) than did temporary lek locations (Table 4).

Land Cover 1.6 km Buffer Model

All Lek Locations Versus Random Locations.—The first series of land cover models I tested was for the 1.6 km buffer. I used 809 lek locations and 809 random locations. The overall model for all years combined was 71.3% accurate (Wilkes' λ = 0.774, $F_{3,1614}$ = 157.194, $P < 0.001$). The discriminant function analysis correctly classified lek locations 81.6% of the time, but misclassified random locations as lek locations 38.9% of the time. Three land cover classes were predictors of lek locations (Table 5). Random locations had significantly more forest area (ha) ($F_{1,1616}$ = 129.798, $P < 0.001$) and cropland area (ha) ($F_{1,1616}$ = 248.009, $P < 0.001$) than lek locations (Fig. 10).

I tested the model by the year of land cover maps to determine if there was any change in the model between years. The model for 1984 had 293 lek locations and 293 random locations. For 1984 images, the model had an overall accuracy of 68.6% (Wilkes' λ = 0.802, $F_{2,586}$ = 72.099, $P < 0.001$). The discriminant function analysis correctly classified lek locations 76.5% of time, but misclassified random locations as lek locations 39.2 % of the time. Two cover classes were predictors of lek locations in 1984: grassland area and forest area.

For 1992 imagery I found 288 lek locations and created 288 random locations. I found that the model for 1992 had an overall accuracy of 74.7% (Wilkes' λ = 0.716,

Table 4. Comparison of slope, elevation, and aspect for traditional lek locations versus temporary lek locations.

		Traditional Leks					Temporary Leks				
		n	Min[a]	Max[b]	Mean	SD[c]	n	Min	Max	Mean	SD
Overall Combined	Slope	3012	0.000	14.484	2.000	1.639	878	0.000	10.607	2.135	1.681
	Elevation	3012	299.000	509.000	404.877	50.940	878	297.000	507.000	404.769	51.515
	Aspect[1]	3012	-1.000	355.601	159.153	105.084	878	-1.000	356.633	160.523	96.078
Chautauqua Hills	Slope	69	0.000	5.151	1.949	0.957	23	0.755	3.931	1.836	0.955
	Elevation	69	299.000	319.000	308.667	5.580	23	297.000	323.000	304.870	7.226
	Aspect[1]	69	-1.000	315.000	157.615	80.903	23	101.300	353.660	234.272	74.289
Flint Hills	Slope	1440	0.000	11.727	1.900	1.643	399	0.000	10.607	1.865	1.525
	Elevation	1440	368.000	479.000	429.873	26.318	399	363.000	477.000	423.932	27.019
	Aspect[1]	1440	-1.000	355.601	160.015	101.516	399	-1.000	358.264	167.186	104.398

continued

Table 4. continued

		Traditional Leks					Temporary Leks				
		n	Min[a]	Max[b]	Mean	SD[c]	n	Min	Max	Mean	SD
Glaciated Region	Slope	201	0.338	7.653	3.050	1.339	53	0.755	6.853	3.537	1.611
	Elevation	201	331.000	408.000	378.164	22.594	53	332.000	401.000	365.358	18.758
	Aspect1	201	0.000	348.690	163.892	95.418	53	26.565	329.036	162.590	83.941
Osage Cuestas	Slope	794	0.000	14.484	1.451	1.417	239	0.000	9.462	1.632	1.381
	Elevation	794	314.000	381.000	342.431	17.975	239	308.000	436.000	346.130	24.377
	Aspect1	794	-1.000	354.806	151.660	115.105	239	-1.000	351.870	152.400	102.238
Smoky Hills	Slope	508	0.000	7.653	2.729	1.688	164	0.000	7.973	3.115	1.906
	Elevation	508	410.000	509.000	455.266	27.670	164	403.000	507.000	448.043	26.989
	Aspect1	508	-1.000	351.870	166.759	104.794	164	-1.000	352.875	157.129	93.838

[1] An aspect of –1.000 is equal to a flat surface.

[a] Minimum

[b] Maximum

[c] Standard Deviation

$F_{2,573}$ = 133.866, $P < 0.001$). The discriminant function analysis correctly classified lek locations 86.8% of time, but misclassified random locations as lek locations 37.5% of the time. The discriminant function analysis again found 2 cover classes that were predictors of lek locations, grassland area, and forest area.

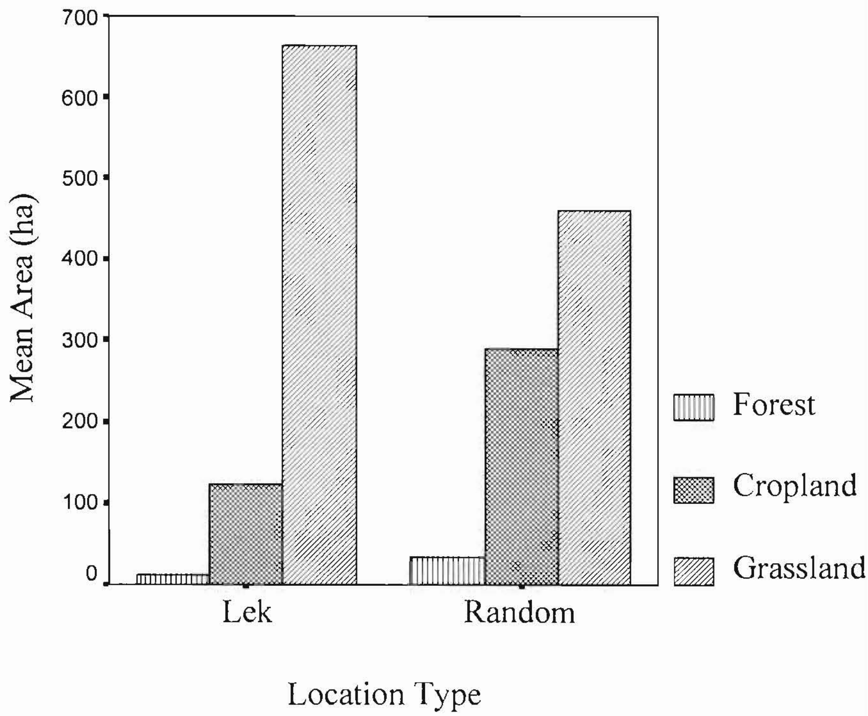
For the 2000 imagery I found 228 lek locations and generated 228 random locations. The 2000 model had an overall accuracy of 72.8% (Wilkes' $\lambda = 0.772$, $F_{2,453}$ = 66.974, $P < 0.001$). The discriminant function analysis correctly classified lek locations 83.3% of time and misclassified random locations as lek locations 37.7% of the time. The discriminant function analysis again found 2 cover classes to be predictors of lek locations: forest area and grassland area.

The first physiographic province I modeled for the 1.6 km buffer was the Flint Hills. It had 343 lek locations and 343 random locations. The model for the Flint Hills had an overall accuracy of 75.1% (Wilkes' $\lambda = 0.691$, $F_{2,683}$ = 152.760, $P < 0.001$). The discriminant function analysis correctly classified lek locations 88.6% of the time. However, random locations were misclassified as lek locations 38.5% of the time. Two cover classes were predictors of lek locations (Table 5). Random locations had significantly more forest area (ha) ($F_{1,684}$ = 108.220, $P < 0.001$) and significantly less grassland area (ha) ($F_{1,684}$ = 253.025, $P < 0.001$) than lek locations (Fig. 11).

The Smoky Hills had 202 lek locations, and I generated 202 random locations. The Smoky Hills model had an overall accuracy of 83.4% (Wilkes' $\lambda = 0.446$, $F_{3,400}$ = 152.931, $P < 0.001$). The discriminant function analysis was able to correctly predict lek locations 92.1% of the time, but misclassified random locations as lek locations 25.4% of

Fig. 10. Comparison of lek location versus random location mean area of a) forest, cropland, and grassland and b) water and urban area within a 1.6 km buffer for all areas combined.

a)


700
600
500
400
300
200
100
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Cropland
Grassland

b)

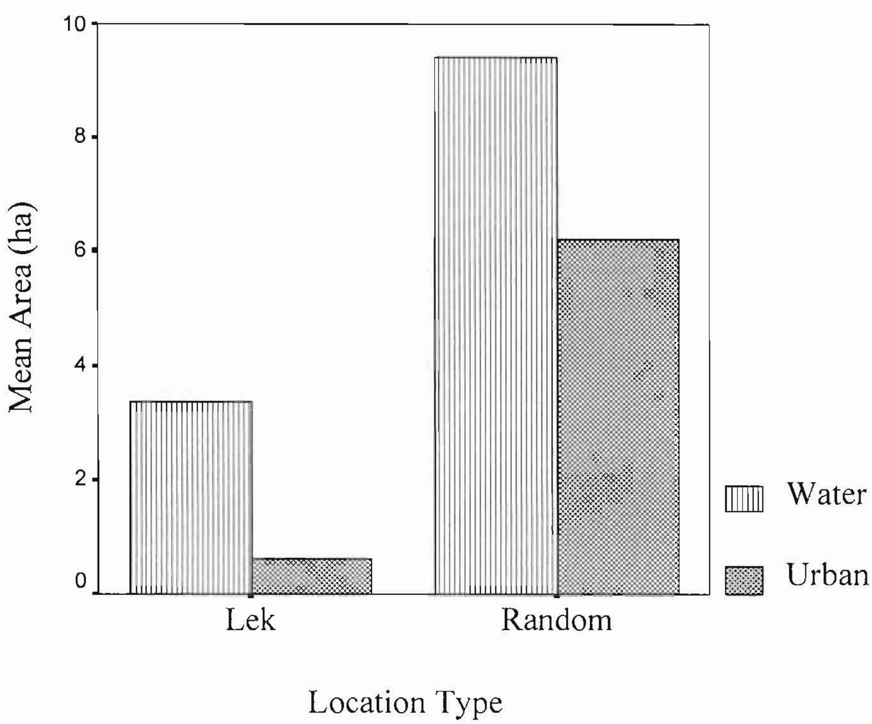
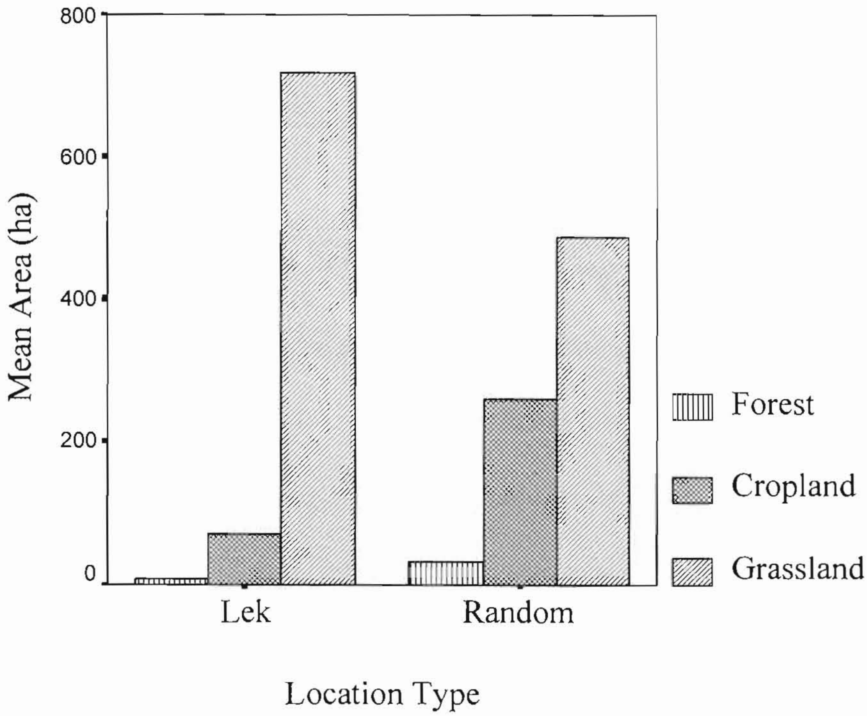
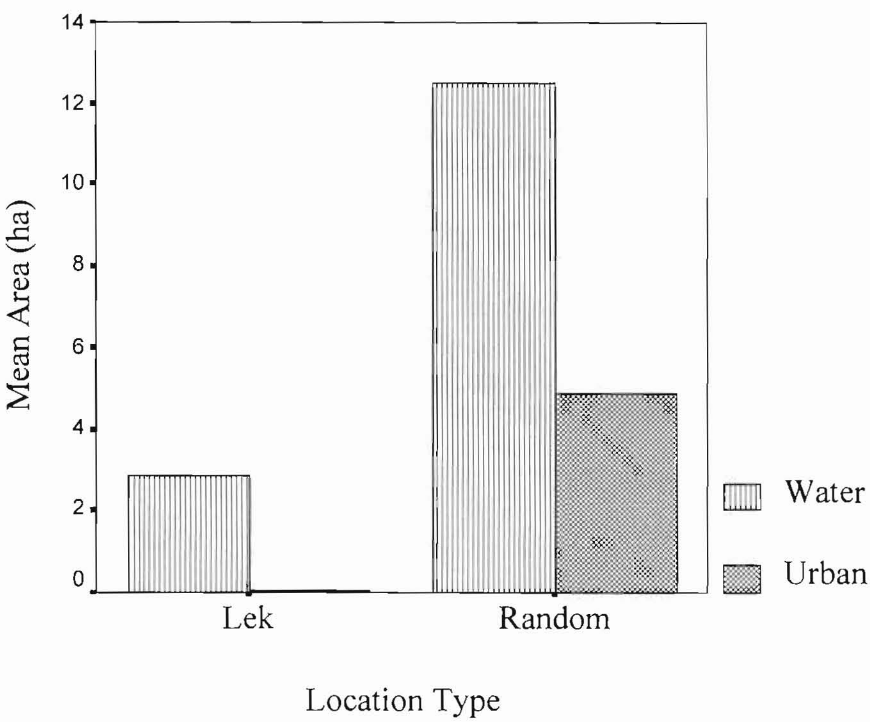

10
8
6
4
2
0
Mean Area (ha)
Lek
Random
Location Type
Water
Urban

Fig. 11. Comparison of lek location versus random location mean area of a) forest, cropland, and grassland and b) water and urban area within a 1.6 km buffer for the Flint Hills.

a)


800
600
400
200
0
Mean Area (ha)
Forest
Cropland
Grassland
Lek
Random
Location Type

b)


14
12
10
8
6
4
2
0
Mean Area (ha)
Water
Urban
Lek
Random
Location Type

the time. The discriminant function analysis found 3 cover classes as predictors of leks (Table5). Smoky Hills leks had significantly more area of grassland ($F_{1,402}$ = 434.492, P < 0.001), water ($F_{1,402}$ =22.744, P < 0.001), and forest ($F_{1,402}$ = 6.732, P < 0.001) than random locations (Fig. 12).

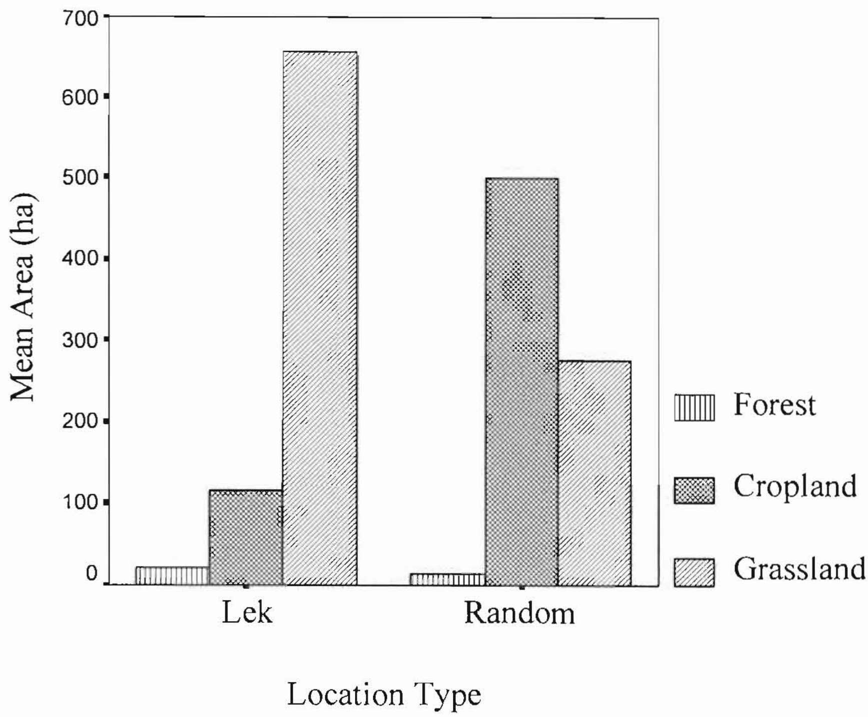
For the Osage Cuestas, I found 188 lek locations and generated 188 random locations. The model for the Osage Cuestas had an overall accuracy of 76.3% (Wilkes' λ = 0.749, $F_{4,371}$ = 31.128, P < 0.001). The discriminant function correctly classified lek locations 95.2% of the time. However, random locations were misclassified as lek locations 42.6% of the time. The discriminant function analysis found 4 cover classes as predictors of lek locations (Table 5). In the Osage Cuestas region lek locations had significantly less forest ($F_{1,374}$ = 92.394, P < 0.001) and urban area ($F_{1,374}$ = 8.3, P = 0.004) than did random locations (Fig. 13).

I found 76 lek locations and generated 76 random locations for the Glaciated Region. The model had an overall accuracy of 73.7 % (Wilkes' λ = 0.68, $F_{2,149}$ = 34.983, P < 0.001). The discriminant function analysis for the Glaciated Region correctly classified lek locations 84.2% of the time, but misclassified random locations as leks 36.8% of the time. Two cover classes were predictors of lek locations (Table 5). Lek locations had significantly more grassland area (ha) ($F_{1,150}$ = 64.849, P < 0.001) than random locations (Fig. 14).

Traditional Leks Versus Temporary Leks.— At the 1.6 km buffer, I also examined traditional versus temporary lek locations by using the land cover classes. The overall model had 614 traditional lek locations and 195 temporary lek locations. The

Fig. 12. Comparison of lek location versus random location mean area of a) forest, cropland, and grassland and b) water and urban within a 1.6 km buffer for the Smoky Hills.

a)


700
600
500
400
300
200
100
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Cropland
Grassland

b)

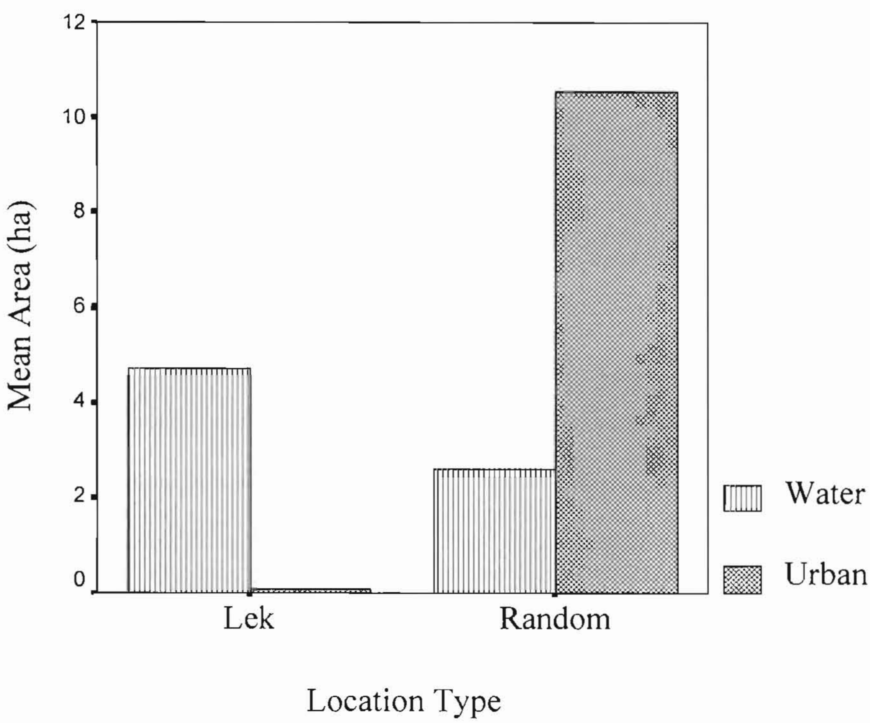
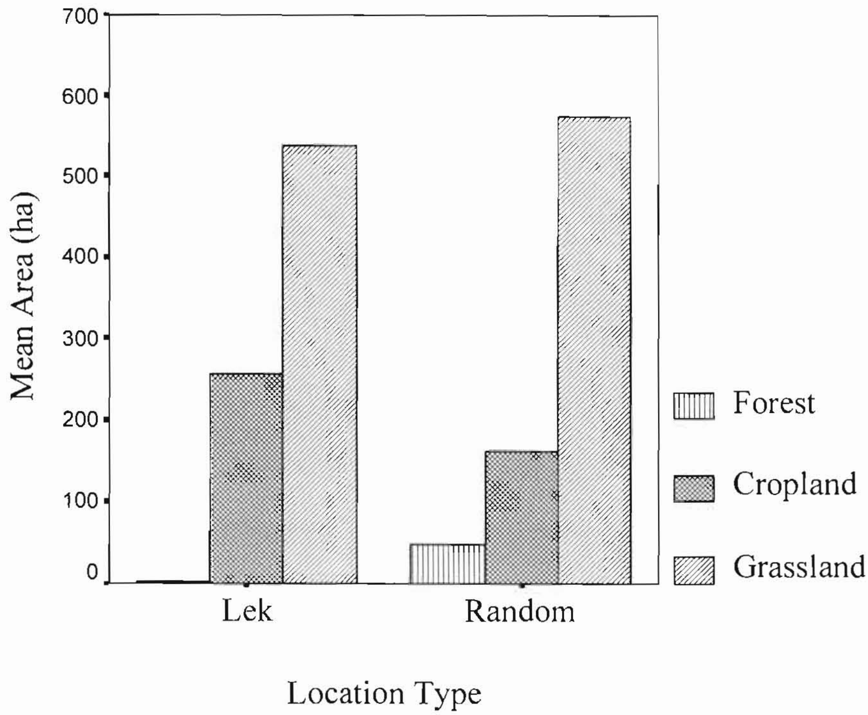

12
10
8
6
4
2
0
Mean Area (ha)
Lek
Random
Location Type
Water
Urban

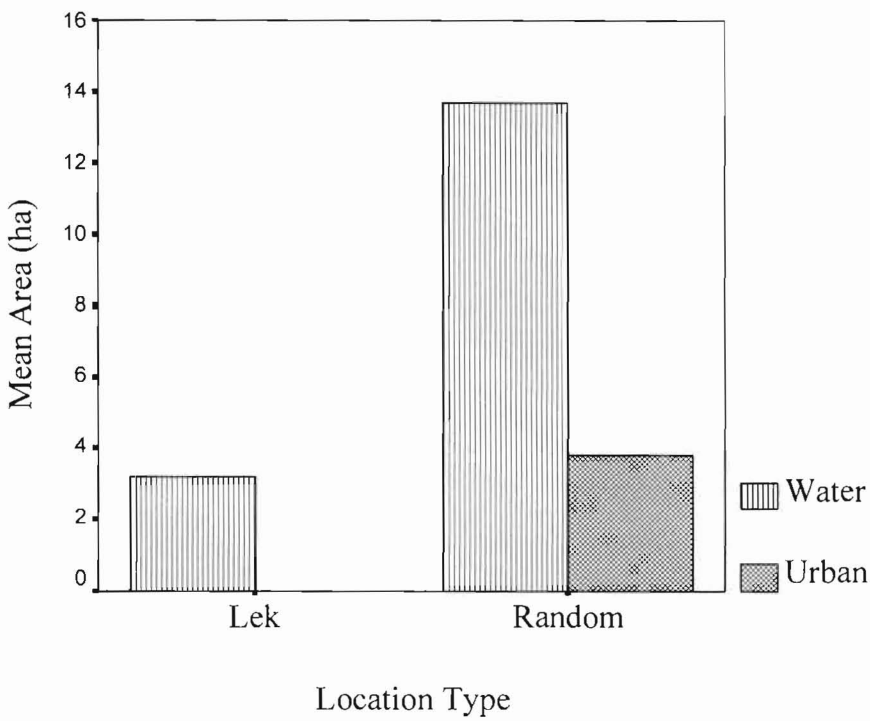
Fig. 13. Comparison of lek location versus random location mean area of a) forest, cropland, and grassland and b) water and urban area within a 1.6 km buffer for the Osage Cuestas.

a)



700
600
500
400
300
200
100
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Cropland
Grassland

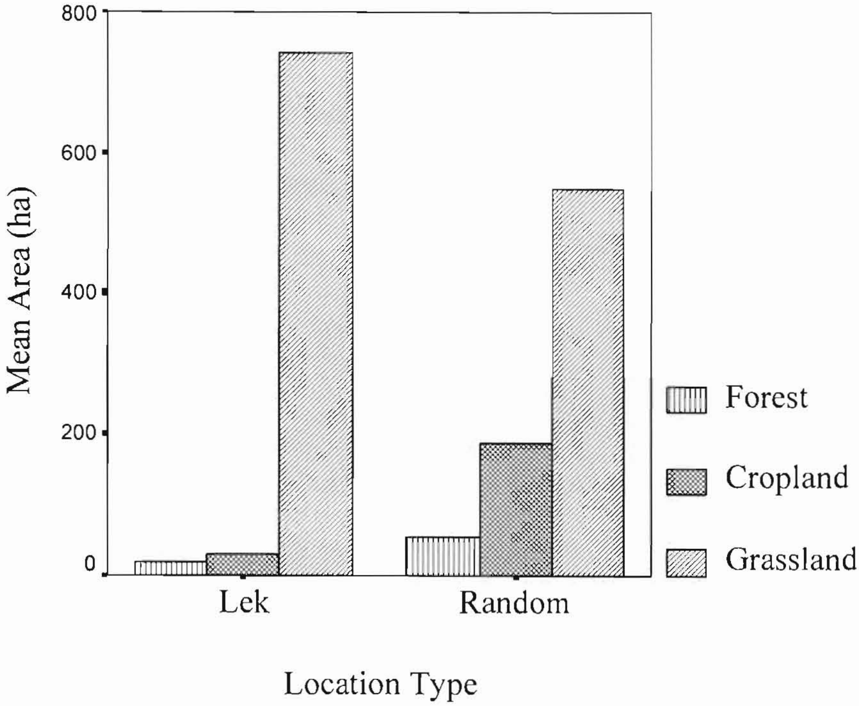
b)



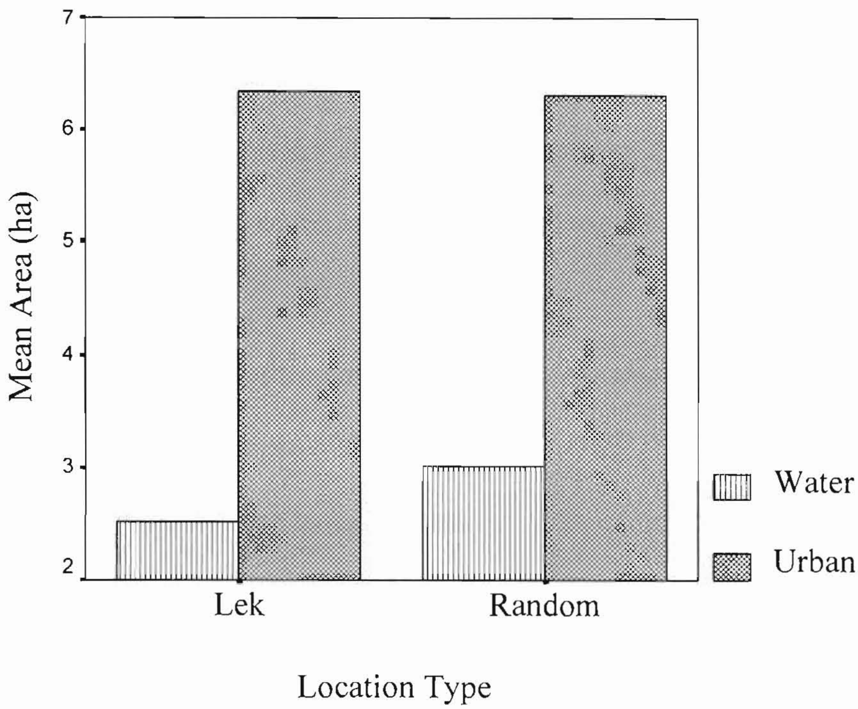
16
14
12
10
8
6
4
2
0
Mean Area (ha)
Lek
Random
Location Type
Water
Urban

Fig. 14. Comparison of lek location versus random location mean area of a) grassland, cropland, and forest and b) urban and water within a 1.6 km buffer for the Glaciated Region

a)


800
600
400
200
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Cropland
Grassland

b)


7
6
5
4
3
2
Mean Area (ha)
Lek
Random
Location Type
Water
Urban

model had an overall accuracy of 70.1% (Wilkes' $\lambda = 0.964$, $F_{1,807} = 29.962$, $P < 0.001$). The model correctly classified traditional lek locations 82.7% of the time. However, it misclassified temporary lek locations as traditional lek locations 69.7% of the time. Only one cover class was a predictor of traditional lek locations (Table 5). Temporary lek locations had significantly more forest area (ha) ($F_{1,807} = 29.962$, $P < 0.001$) than traditional lek locations (Fig. 15).

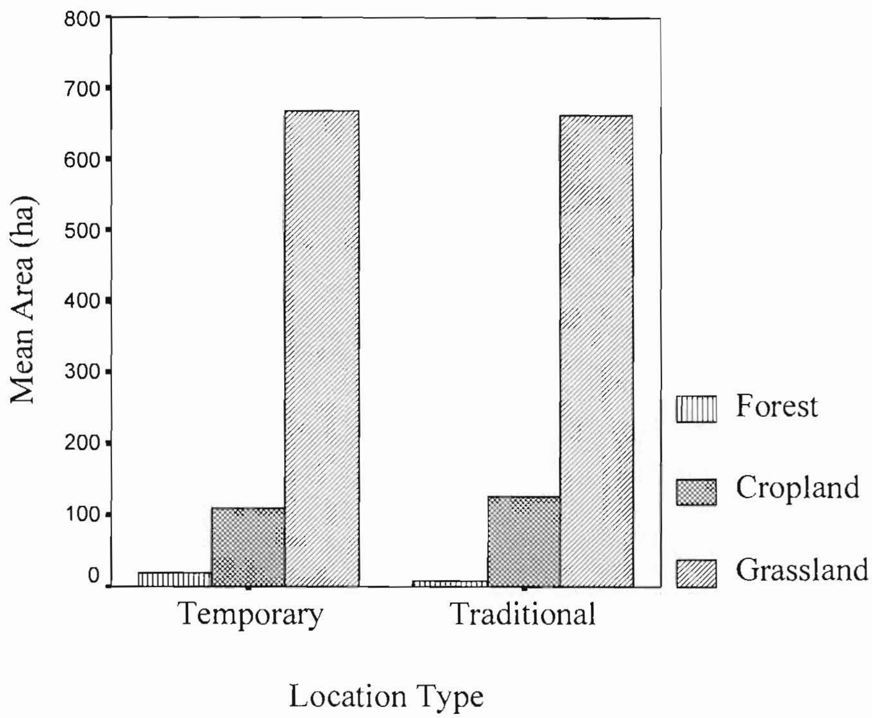
When examining traditional versus temporary lek locations in the 1.6 km buffer, the Flint Hills had 253 traditional lek locations and 90 temporary lek locations. The model had an overall accuracy of 58.9% (Wilkes' $\lambda = 0.976$, $F_{2,340} = 4.154$, $P = 0.0165$) and correctly classified traditional lek locations 60.1% of the time, but misclassified temporary lek locations as traditional lek locations 55.6% of the time. Two cover classes were predictors (Table 5). Traditional lek locations had significantly more grassland area (ha) ($F_{1,341} = 4.311$, $P = 0.039$) than did temporary lek locations (Fig. 16).

The Smoky Hills had 146 traditional lek locations and 56 temporary lek locations. The overall accuracy of the land cover model was 76.2% (Wilkes' $\lambda = 0.898$, $F_{1,200} = 22.810$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 93.8% of the time. However, it misclassified temporary lek locations as traditional lek locations 69.6% of the time. Only 1 cover class was found to be a predictor of traditional versus temporary lek locations (Table 5). Temporary lek locations had significantly more forest area (ha) ($F_{1,200} = 22.810$, $P < 0.001$) within the 1.6 km buffer than traditional lek locations (Fig 17).

The Osage Cuestas had 154 traditional lek locations and 34 temporary lek

Fig. 15. Comparison of traditional versus temporary lek location mean area of a) forest, cropland, and grassland and b) water and urban within 1.6 km buffer for all routes combined.

a)


800
700
600
500
400
300
200
100
0
Mean Area (ha)
Forest
Cropland
Grassland
Temporary
Traditional
Location Type

b)

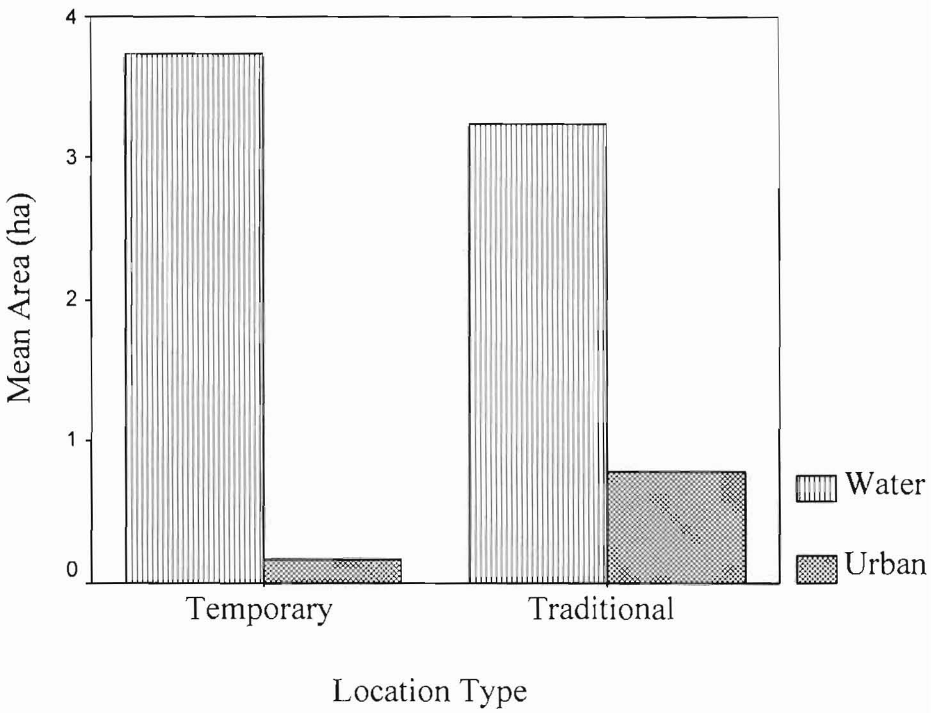
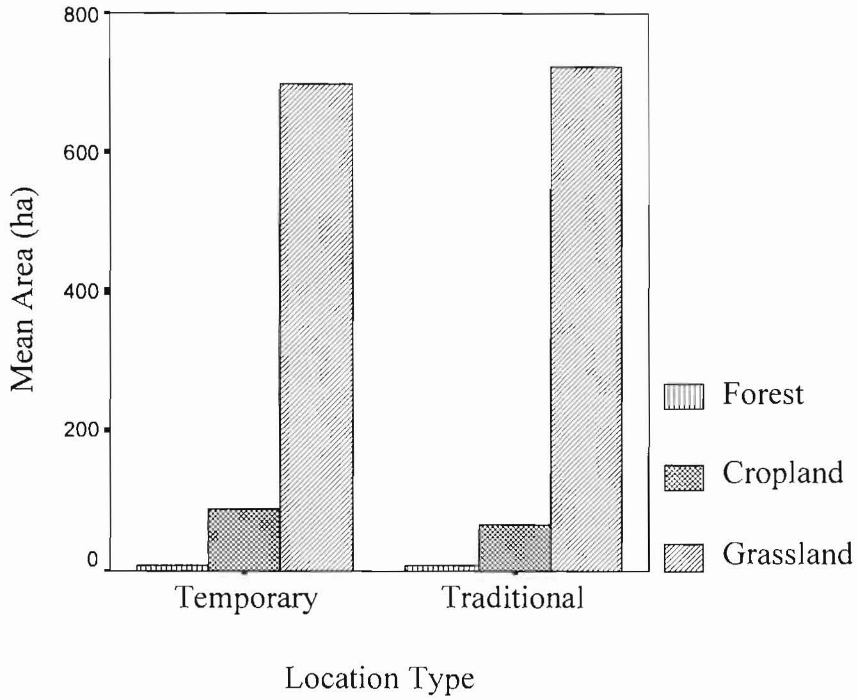

4
3
2
1
0
Mean Area (ha)
Water
Urban
Temporary
Traditional
Location Type

Fig. 16. Comparison of traditional versus temporary lek location mean area of a) forest, cropland, and grassland and b) water and urban within 1.6 km buffer for the Flint Hills.

a)


800
600
400
200
0
Mean Area (ha)
Forest
Cropland
Grassland
Temporary
Traditional
Location Type

b)

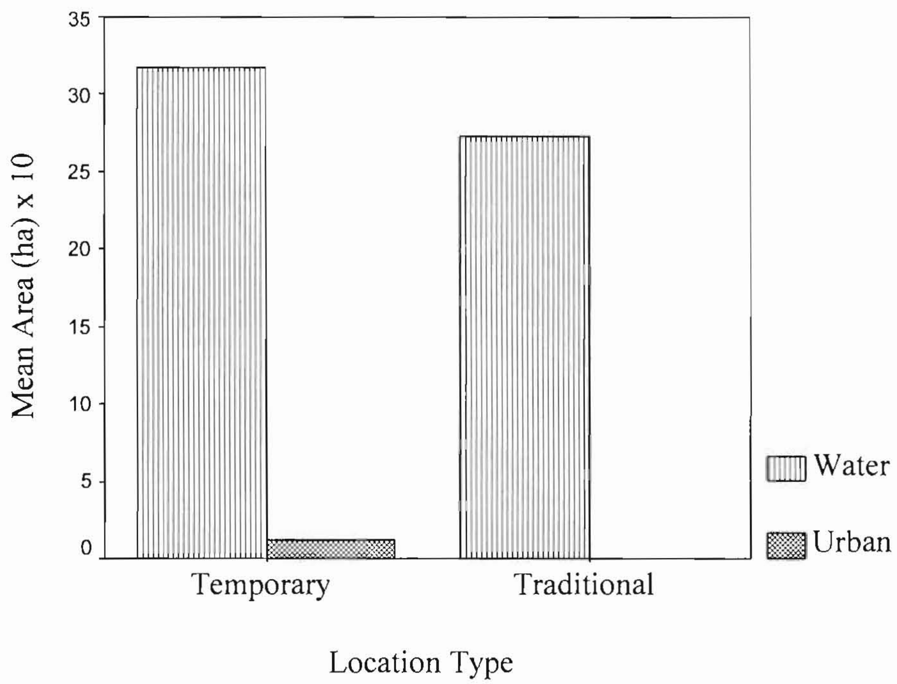
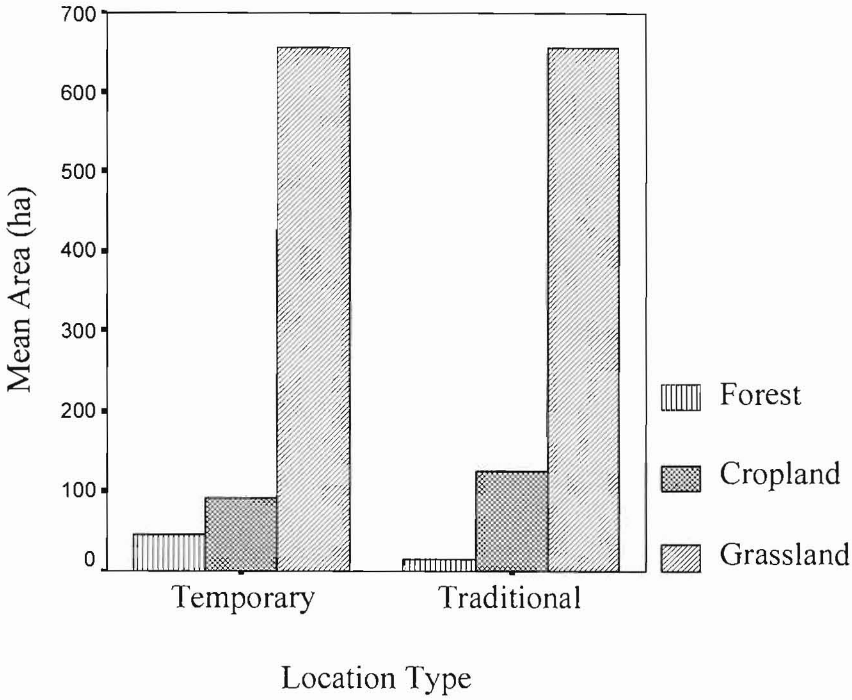
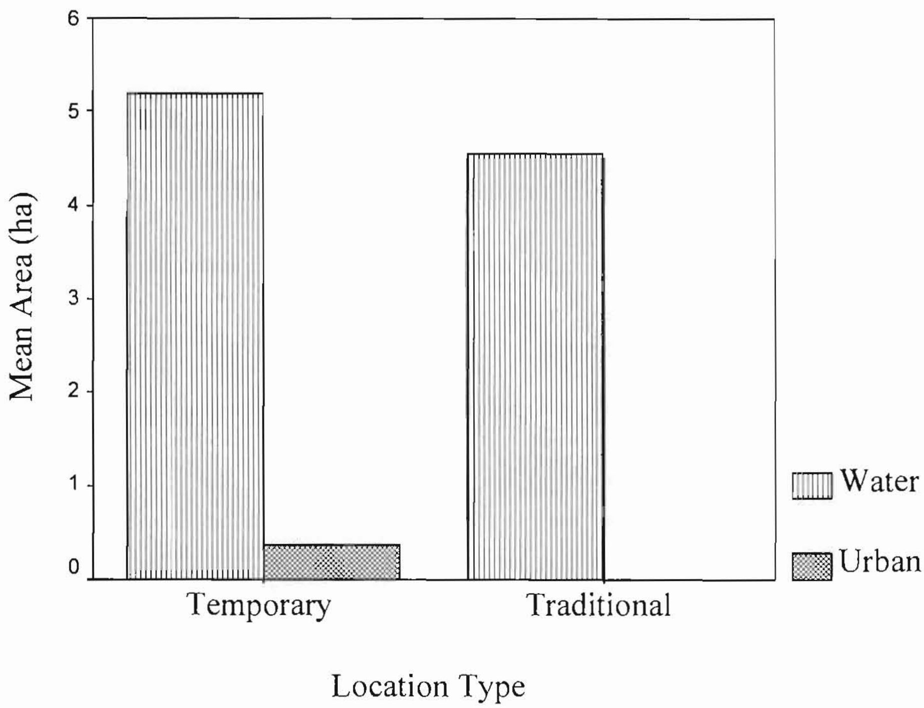

35
30
25
20
15
10
5
0
Mean Area (ha) x 10
Water
Urban
Temporary
Traditional
Location Type

Fig. 17. Comparison of traditional versus temporary lek location mean area of a) forest, cropland, and grassland and b) water and urban within 1.6 km buffer for the Smoky Hills.

a)


700
600
500
400
300
200
100
0
Mean Area (ha)
Forest
Cropland
Grassland
Temporary
Traditional
Location Type

b)


6
5
4
3
2
1
0
Mean Area (ha)
Water
Urban
Temporary
Traditional
Location Type

locations. The model had an overall accuracy of 72.9% (Wilkes' $\lambda = 0.935$, $F_{1,186} = 12.992$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 79.2% of the time, but misclassified temporary lek locations as traditional locations 55.9% of the time. Only 1 cover class was a predictor of traditional lek locations in the Osage Cuestas (Table 5). Temporary lek locations had significantly more forest area (ha) ($F_{1,186} = 12.992$, $P < 0.001$) than traditional lek locations (Fig 18).

The Glaciated Region had 61 traditional lek locations and 15 temporary lek locations. There were no significant differences between traditional and temporary lek locations within the 1.6 km buffer, therefore no discriminant function analysis was run.

Landscape Metrics Model

All Lek Locations Versus Random Locations.—I examined the association of landscape metrics calculated for the 1.6 km buffer. The landscape metrics model had an overall accuracy of 76.3% (Wilkes' $\lambda = 0.689$, $F_{14,1603} = 51.667$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 84.2%, but misclassified random locations as lek locations 31.6% of the time. The model found 14 landscape metrics predictors of lek locations versus random locations (Table 6). Lek locations had significantly larger grassland median patch sizes ($F_{1,1616} = 191.654$, $P < 0.001$) and grassland mean patch sizes ($F_{1,1616} = 286.110$, $P < 0.001$) than random locations (Figs. 19 and 20).

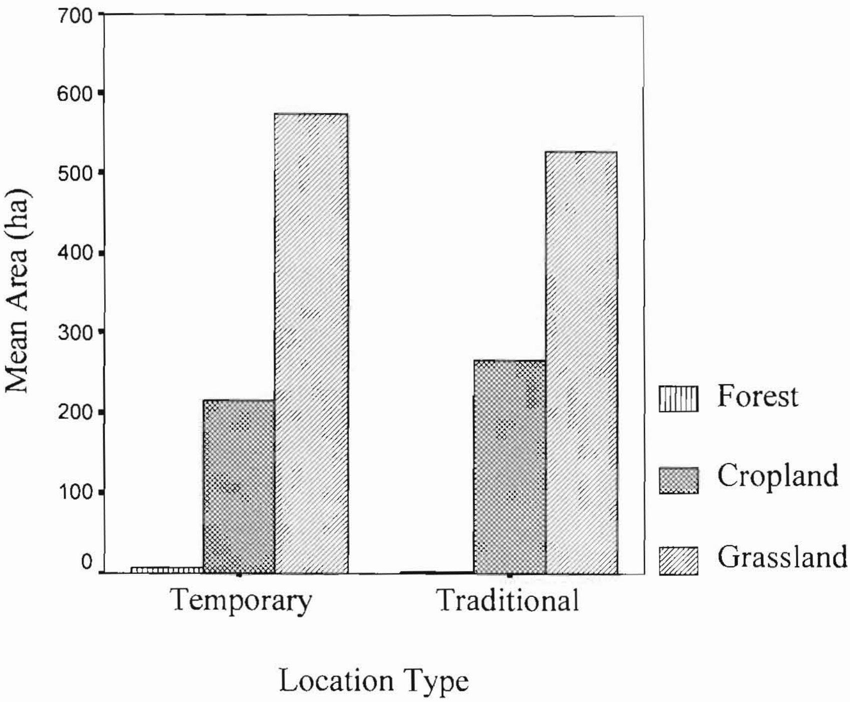
The Flint Hills region had an overall model accuracy of 74.6% (Wilkes' $\lambda = 0.692$, $F_{6,679} = 50.364$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 80.1% of the time. However, it misclassified random locations 30.9% of the

Table 5. Land cover predictive models for 1.6 km buffer for lek locations versus random locations and traditional leks versus temporary leks for all areas combined and physiographic provinces. Variables are listed in order of discriminating ability from strongest to weakest.

	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Overall Model	grassland area, cropland area, forest area	forest area
Flint Hills	grassland area, forest area	grassland area, water area
Glaciated Region	grassland area, water area	no predictors
Osage Cuestas	cropland area, urban area, grassland area, forest area	forest area
Smoky Hills	grassland area, water area, forest area	forest area

Fig. 18. Comparison of traditional versus temporary lek location mean area of a) forest, cropland, and grassland and b) water and urban within the 1.6 km buffer for the Osage Cuestas.

a)


700
600
500
400
300
200
100
0
Mean Area (ha)
Temporary
Traditional
Location Type
Forest
Cropland
Grassland

b)

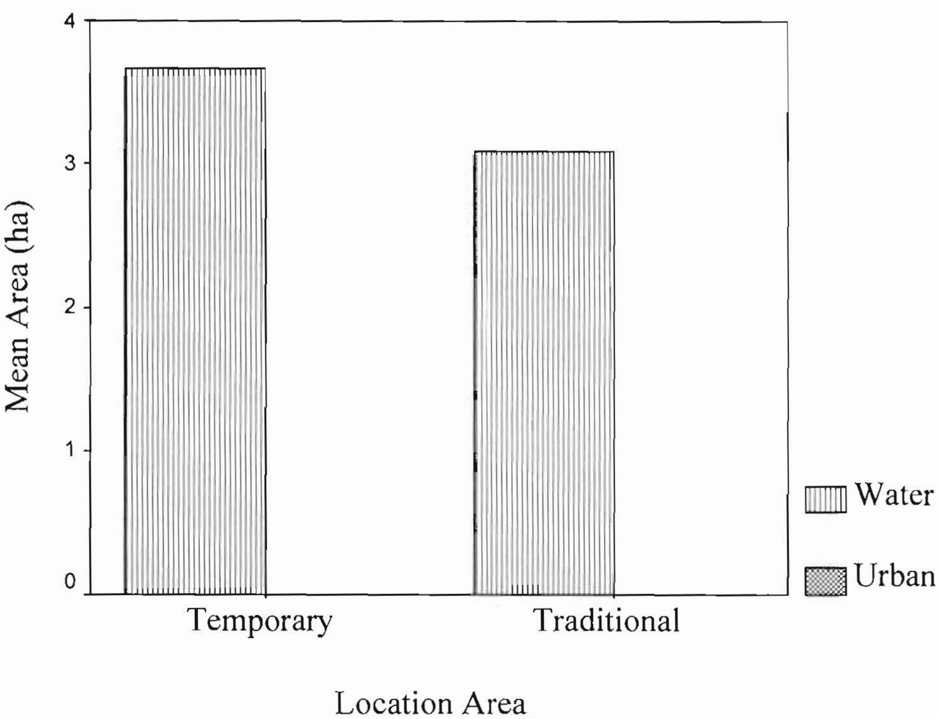
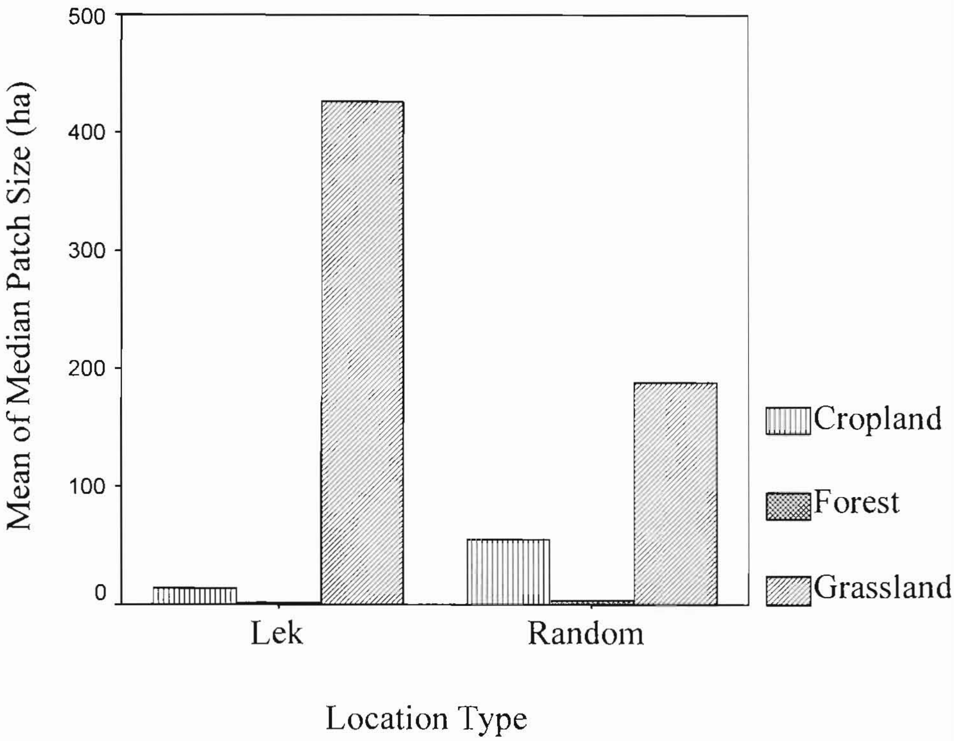
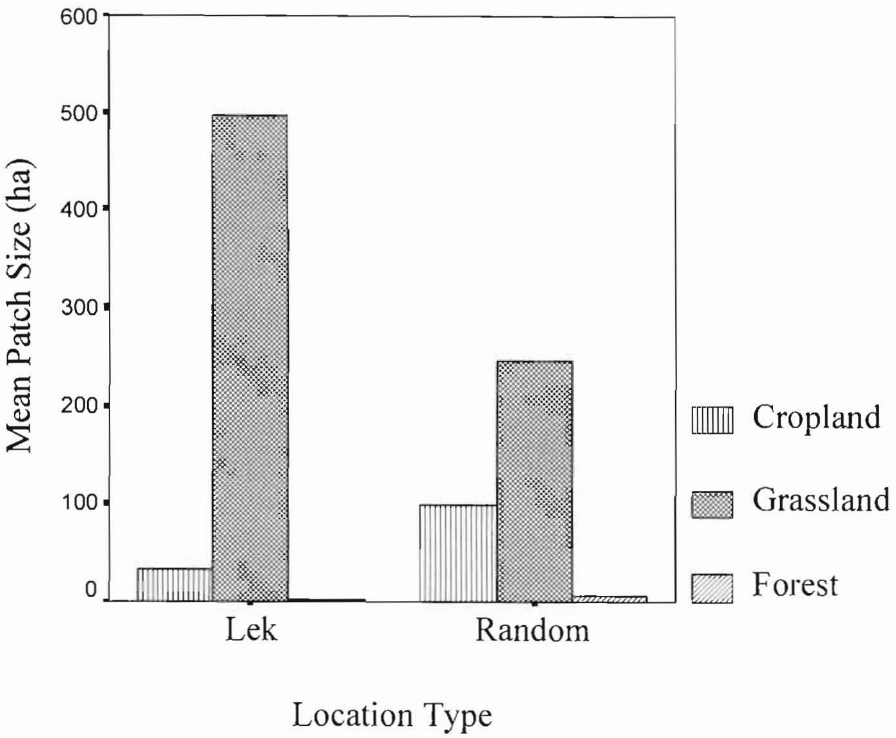

4
3
2
1
0
Mean Area (ha)
Temporary
Traditional
Location Area
Water
Urban

Fig. 19. Comparison of lek location versus random location mean of median patch size for, cropland, forest, and grassland within the 1.6 km buffer for all lek locations combined.



Mean of Median Patch Size (ha)
500
400
300
200
100
0
Lek
Random
Location Type
Cropland
Forest
Grassland

Fig. 20. Comparison of lek location versus random location mean patch size for cropland, forest, and grassland within the 1.6 km buffer for all lek locations combined.



600
500
400
300
200
100
0
Mean Patch Size (ha)
Lek
Random
Location Type
Cropland
Grassland
Forest

time. Of the 33 landscape metrics only 6 were predictors of lek locations (Table 6). Mean grassland patch size ($F_{1,684} = 165.91$, $P < 0.001$) for lek locations was larger than random locations (Fig. 21).

The Smoky Hills region had an overall model accuracy of 87.6% (Wilkes' λ = 0.446, $F_{8,395} = 61.365$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 90.1% of the time, but random locations were misclassified as lek locations 14.9% of the time. Eight landscape metrics were predictors of lek locations (Table 6).

The model for the Osage Cuestas had an overall accuracy of 80.6% (Wilkes' λ = 0.588, $F_{6,369} = 43.054$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 81.4% of the time. However, it misclassified random locations as lek locations 20.2% of the time. The model found 6 landscape metrics as predictors of lek locations (Table 6). Lek locations had significantly larger mean cropland patch sizes ($F_{1,374} = 16.814$, $P < 0.001$) than random locations (Fig. 22).

The model for the Glaciated Region had an overall accuracy of 78.9% (Wilkes' λ = 0.529, $F_{3,148} = 43.929$, $P < 0.001$). The discriminant function analysis correctly classified random locations 80.3% of the time, but misclassified lek locations as random locations 22.4% of the time. Three landscape metrics were found by the discriminant function analysis to be predictors of the lek locations (Table 6). Lek locations had significantly larger mean grassland patch size ($F_{1,150} = 87.545$, $P < 0.001$) and a smaller mean grassland patch fractal dimension ($F_{1,150} = 27.734$, $P < 0.001$) than did random locations (Figs. 23 and 24).

Fig. 21. Comparison of lek location versus random location mean patch size for cropland, forest, and grassland within the 1.6 km buffer for the Flint Hills.

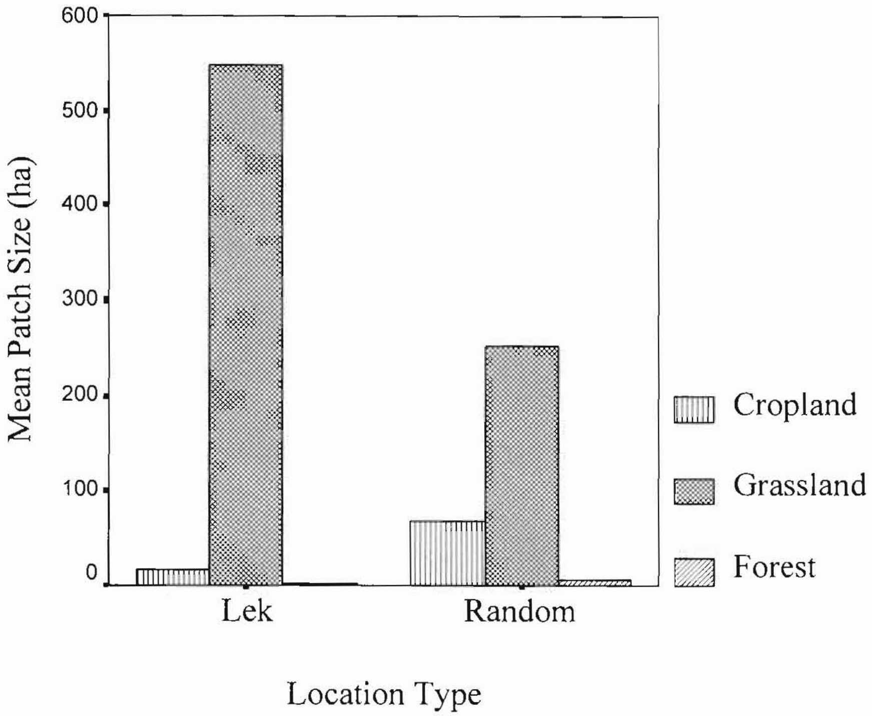

600
500
400
300
200
100
0
Mean Patch Size (ha)
Lek
Random
Location Type
Cropland
Grassland
Forest

Fig. 22. Comparison of lek locations versus random location mean patch size for cropland, forest, and grassland within the 1.6 km buffer the Osage Cuestas.

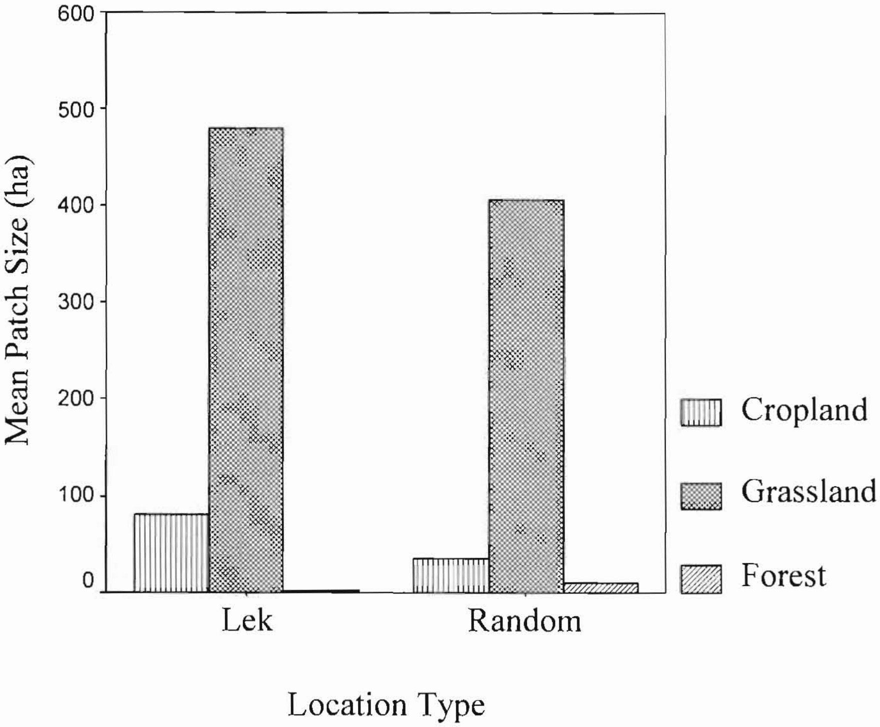
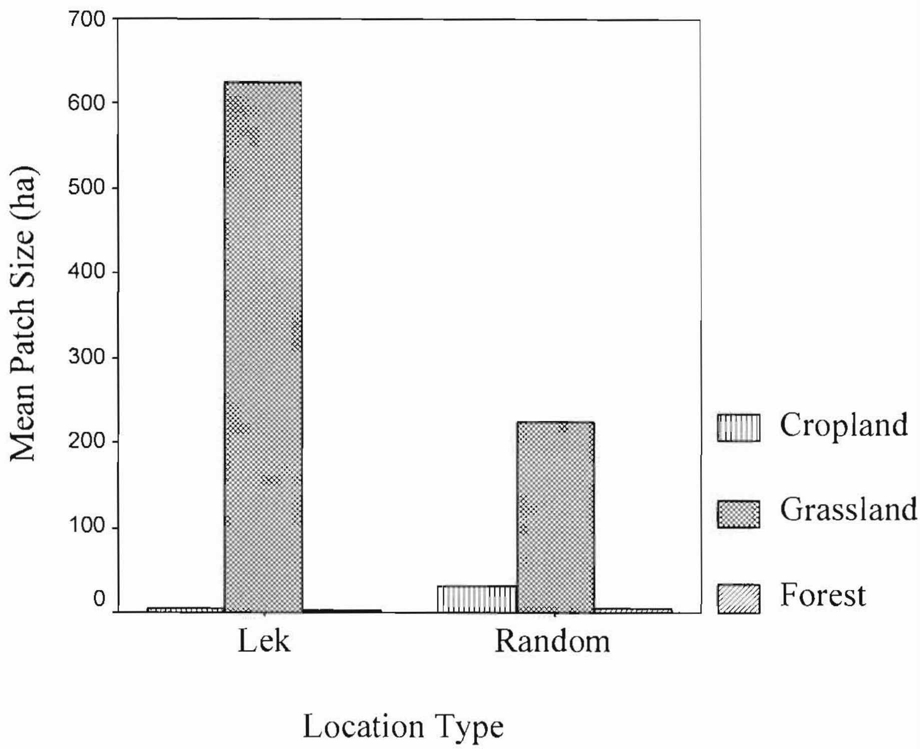
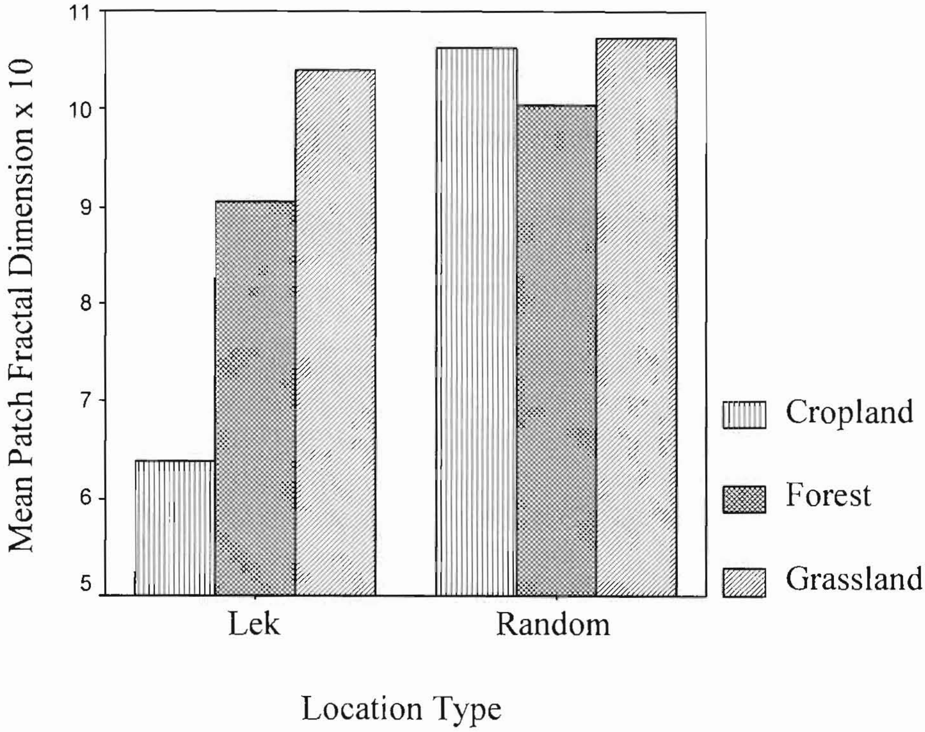

600
500
400
300
200
100
0
Mean Patch Size (ha)
Lek
Random
Location Type
Cropland
Grassland
Forest

Fig. 23. Comparison of lek location versus random location mean patch size for cropland, forest, and grassland within the 1.6 km buffer for the Glaciated Region.



Mean Patch Size (ha)
700
600
500
400
300
200
100
0
Lek
Random
Location Type
Cropland
Grassland
Forest

Fig. 24. Comparison of lek location versus random location mean patch fractal dimension for cropland, forest, and grassland within the 1.6 km buffer for the Glaciated Region.



Mean Patch Fractal Dimension x 10
11
10
9
8
7
6
5
Lek
Random
Location Type
Cropland
Forest
Grassland

Traditional Leks Versus Temporary Leks.—I found that for the overall area traditional versus temporary lek locations had an accuracy of 55.0% (Wilkes' $\lambda = 0.990$, $F_{1,807} = 7.856$, $P = 0.005$). The discriminant function analysis correctly classified traditional lek locations 56.0% of the time, but misclassified temporary lek locations as traditional 48.2% of the time. Only one landscape metric was a predictor of traditional lek locations (Table 6). Temporary lek locations had significantly larger mean forest patch edge ($F_{1,807} = 7.856$, $P = 0.005$) than traditional lek locations (Fig. 25).

I also tested the predictability of landscape metrics for traditional versus temporary lek locations at the physiographic province level. I found that the Flint Hills model had an overall accuracy of 56.9% (Wilkes' $\lambda = 0.982$, $F_{1,341} = 6.338$, $P = 0.012$). The discriminant function analysis correctly classified traditional lek locations 59.3% of the time. However temporary lek locations were misclassified as traditional lek locations 50.0% of the time. Only 1 landscape metric was a predictor of traditional versus temporary lek locations (Table 6). Traditional leks had significantly less forest patch edge ($F_{1,341} = 6.338$, $P = 0.012$) than temporary lek locations (Fig. 26).

The Smoky Hills region had an overall model accuracy of 68.8% (Wilkes' $\lambda = 0.937$, $F_{1,200} = 13.523$, $P < 0.001$). The model correctly classified traditional lek locations 76.0% of the time, but misclassified temporary lek locations as traditional 50.0% of the time. Again only 1 landscape metric was a predictor of traditional lek locations (Table 6). Traditional lek locations had a significantly larger mean forest area weighted patch fractal dimension then did temporary lek locations (Fig. 27).

Fig. 25. Comparison of traditional versus temporary lek location mean patch edge for cropland, forest, and grassland within the 1.6 km buffer for all lek locations combined.

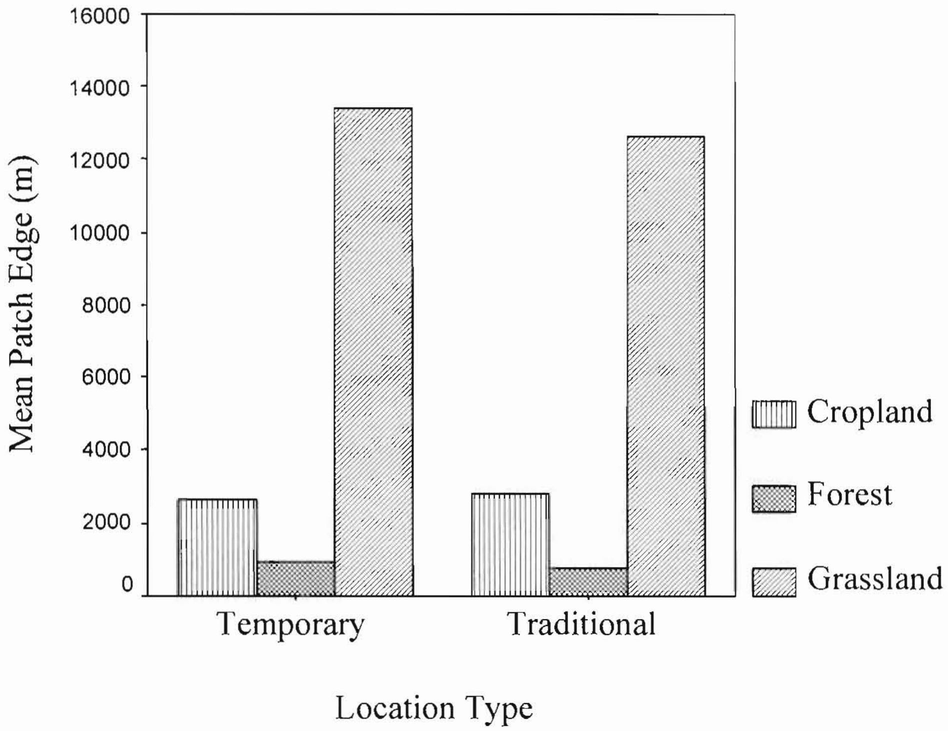
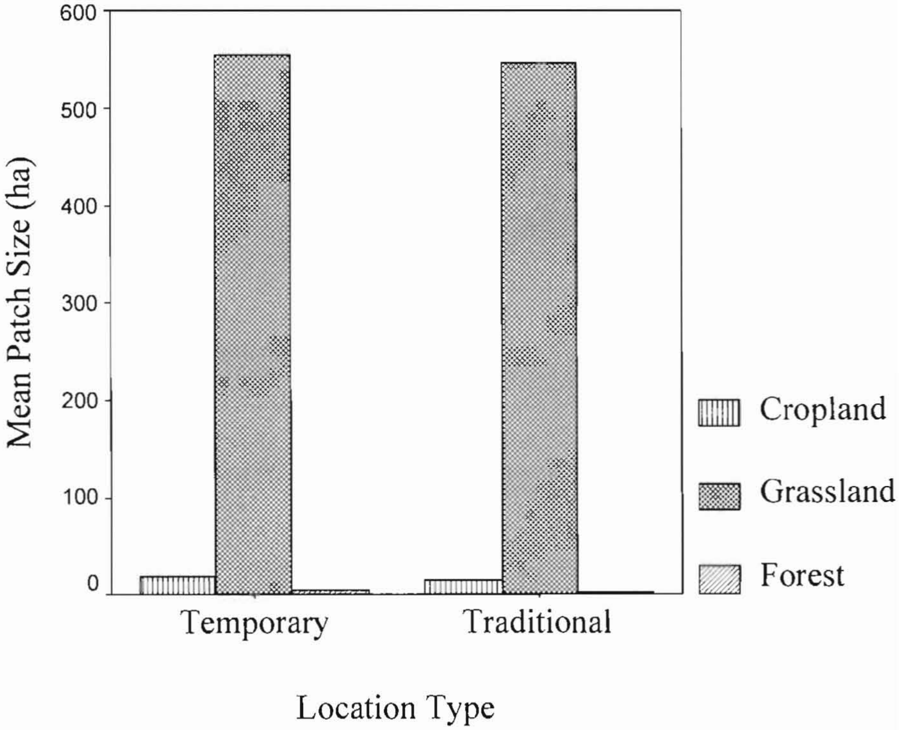
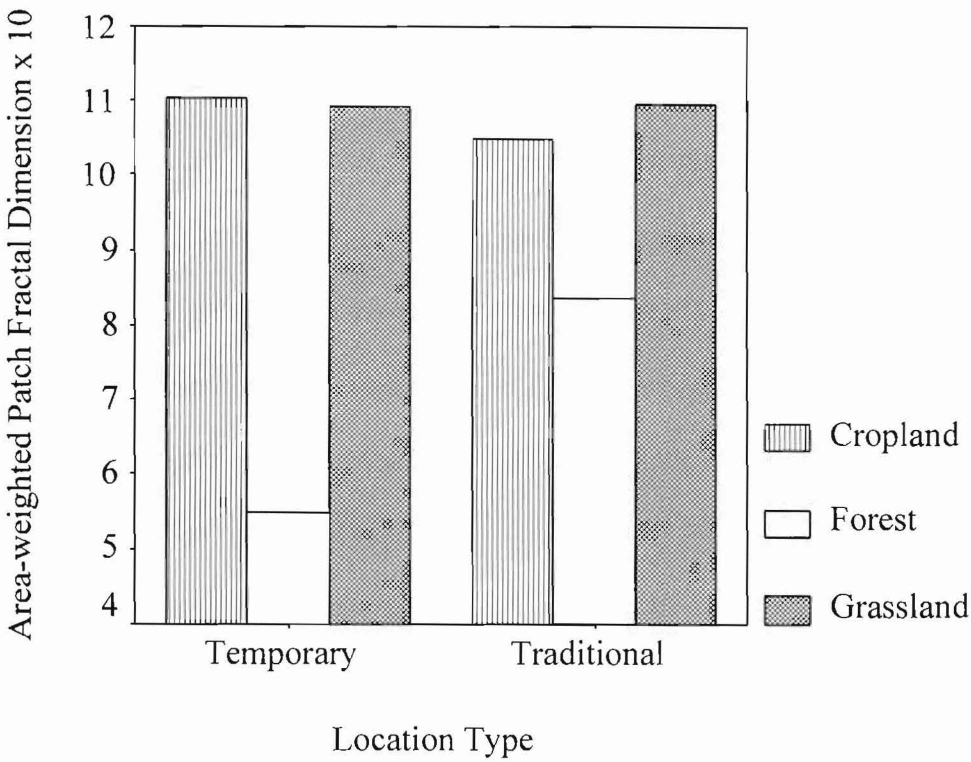

16000
14000
12000
10000
8000
6000
4000
2000
0
Mean Patch Edge (m)
Temporary
Traditional
Location Type
Cropland
Forest
Grassland

Fig. 26. Comparison of traditional versus temporary lek locations mean patch size for cropland, forest, and grassland within the 1.6 km buffer for the Flint Hills.



600
500
400
300
200
100
0
Mean Patch Size (ha)
Temporary
Traditional
Location Type
Cropland
Grassland
Forest



Area-weighted Patch Fractal Dimension x 10
12
11
10
9
8
7
6
5
4
Temporary
Traditional
Location Type
Cropland
Forest
Grassland

The Osage Cuestas had an overall model accuracy of 73.4% (Wilkes' $\lambda = 0.936$, $F_{1,186} = 12.713$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 77.9% of the time. However, it misclassified temporary lek locations as traditional 47.1% of the time. Forest edge density was the only landscape metric found to be a predictor of traditional lek locations (Table 6).

The Glaciated Region had an overall model accuracy of 89.5% (Wilkes' $\lambda = 0.651$, $F_{3,72} = 12.852$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations within the Glaciated Region 90.2% of the time. Temporary lek locations were misclassified as traditional 13.3% of the time. Three predictors were found for traditional versus temporary lek locations (Table 6).

Land Cover 4.0 km Buffer Model

All Lek Locations Versus Random Locations.—In modeling the associations of land cover with greater prairie-chicken lek locations, I also used a 4.0 km buffer with the same number of lek and random locations as the 1.6 km buffer. The overall model for the 4.0 km buffer was 68.5% accurate (Wilkes' $\lambda = 0.793$, $F_{3,1614} = 140.813$, $P < 0.001$) in predicting lek locations. The discriminant function analysis correctly classified 75.3 % of lek locations and misclassified random points as lek locations 38.4% of the time. Three of the 5 cover classes were associated with lek locations (Table 7). For the overall model, random locations had significantly more forest area (ha) ($F_{1,1616} = 96.559$, $P < 0.001$) and water area (ha) ($F_{1,1616} = 26.43$, $P < 0.001$) than did lek locations (Fig 28).

I also tested each year separately to determine if there was any difference in the quality of the imagery or if processing had a major effect on land cover associations. The

Table 6. Landscape metrics predictive models for 1.6 km buffer for lek locations versus random locations and traditional lek locations versus temporary lek locations for all areas combined and physiographic provinces. Variables are listed in order of discriminating ability from strongest to weakest.

	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Overall Model	grassland mean shape index, grassland median patch size, cropland mean patch size, forest edge density, grassland edge density, total cropland edge, forest mean shape index, cropland mean perimeter area ratio, grassland mean perimeter area ratio, grassland area weighted mean patch fractal dimension, cropland mean patch edge, grassland area weighted mean shape index, grassland mean patch size, grassland mean patch edge	mean forest patch edge
Flint Hills	total forest edge, cropland mean patch size, grassland mean perimeter area ratio, forest median patch size, median grassland patch size, mean grassland patch size	mean forest patch edge
Glaciated Region	mean grassland patch size, mean grassland patch edge, mean grassland patch fractal dimension	forest edge density, cropland edge denisty, number of cropland patches

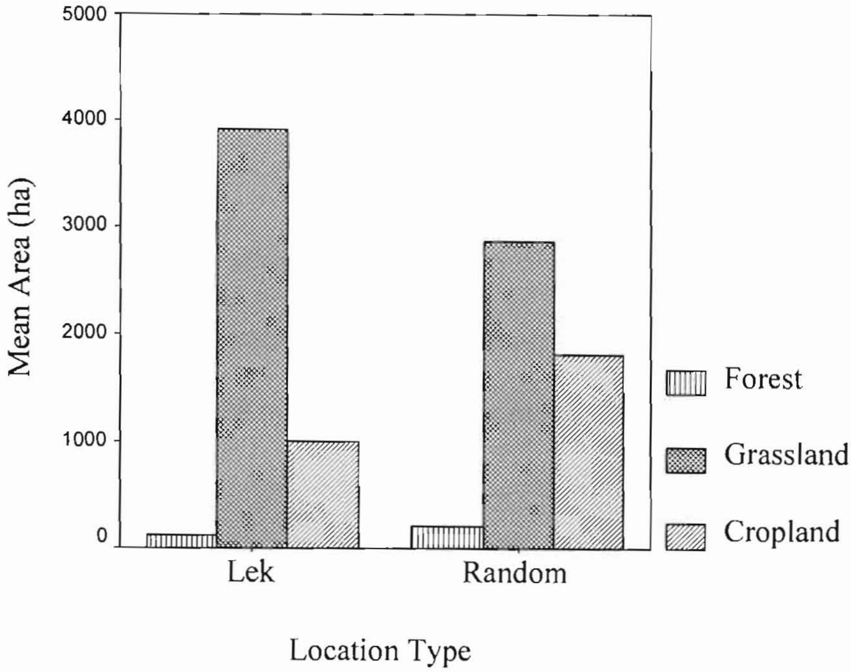
Continued

Table 6. continued.

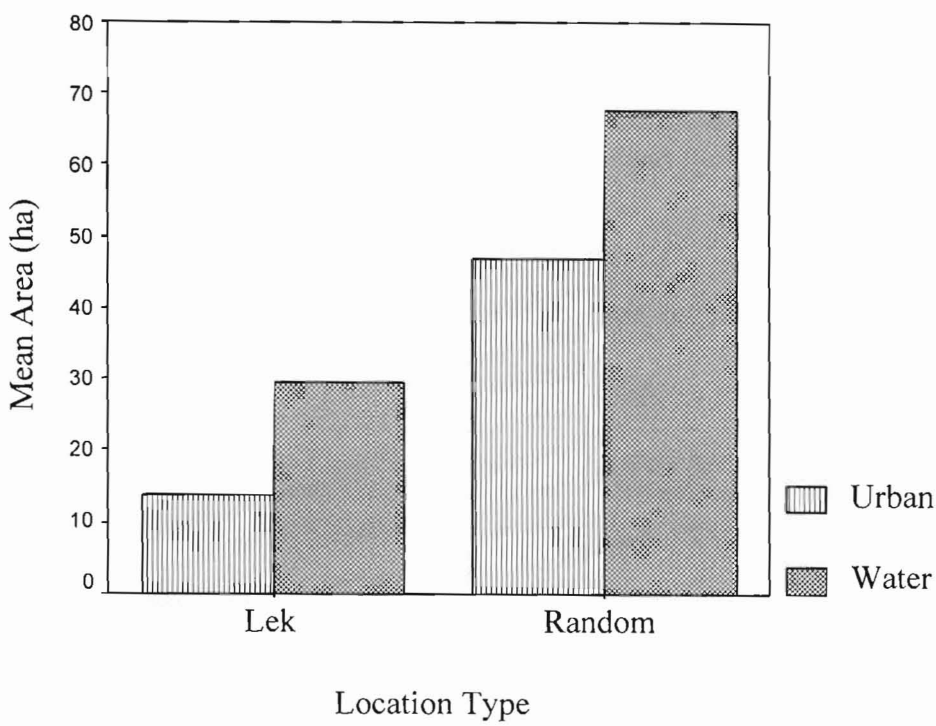
	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Osage Cuestas	forest edge density, forest mean patch fractal dimension, forest mean perimeter area ratio, cropland mean shape index, cropland median patch size, cropland mean patch size	forest edge density
Smoky Hills	grassland mean patch size, grassland mean patch edge, grassland median patchsize, grassland mean shape index, grassland area weighted mean patch fractal dimension, grassland mean patch fractal dimension, cropland area weighted mean shape index, cropland total edge	mean forest area weighted patch fractal dimension

Fig. 28. Comparison of lek location versus random location mean area of a) forest, grassland, and cropland and b) urban and water within the 4.0 km buffer for all lek locations combined.

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Grassland
Cropland

b)


80
70
60
50
40
30
20
10
0
Mean Area (ha)
Lek
Random
Location Type
Urban
Water

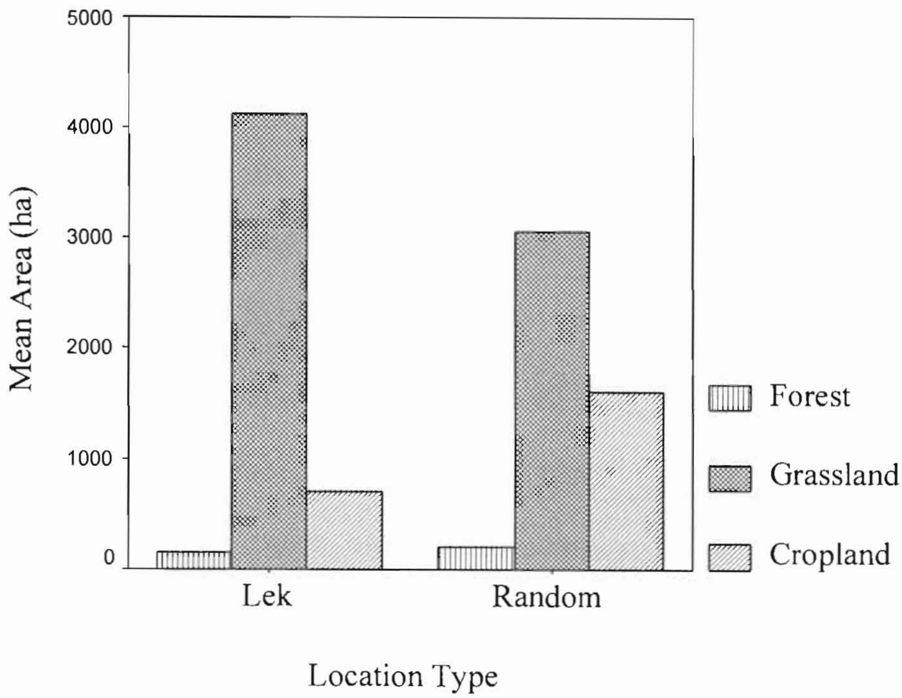
first yearly model tested was for the 1984 images. The model had an overall accuracy of 69.9% (Wilkes' $\lambda = 0.781$, $F_{3,580} = 54.639$, $P < 0.001$). The discriminant function analysis for 1984 correctly classified lek locations 75.1% of time and misclassified random locations as leks 36.0% of the time. Three cover classes were predictors of lek locations (Table 7).

For 1992, the model had an overall accuracy of 69.6 % (Wilkes' $\lambda = 0.789$, $F_{2,573} = 76.717$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 78.1% of the time and misclassified random locations as lek locations 38.9% of the time. Grassland area and forest area were predictors of lek locations in 1992.

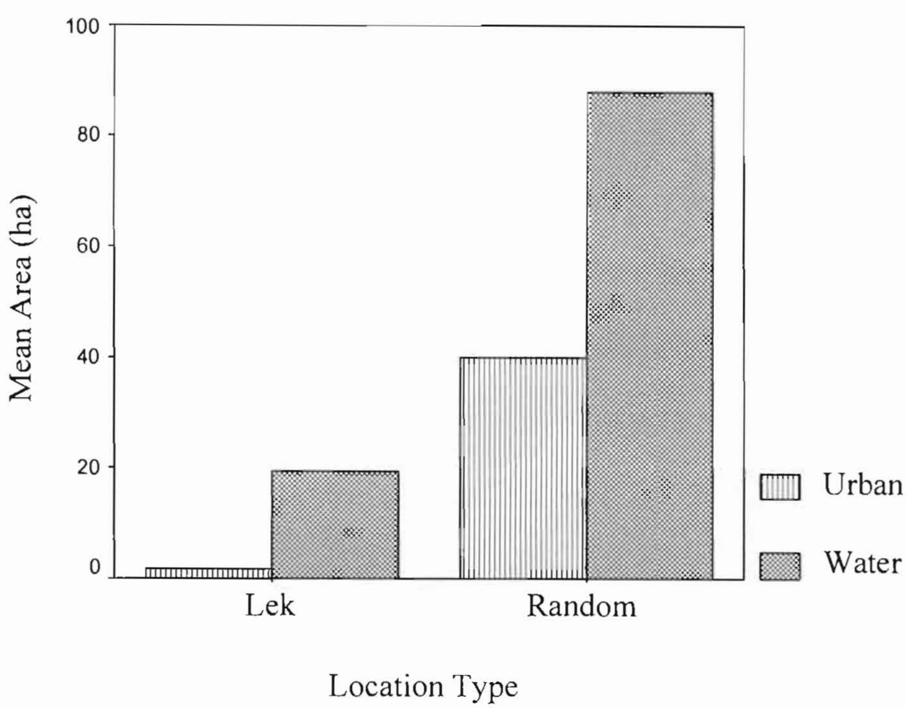
For 2000 the model had an overall accuracy of 66.3% (Wilkes' $\lambda = 0.801$, $F_{2,553} = 56.435$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 71.9% of the time and misclassified random locations as lek locations 39.3 % of the time. The 2 land cover classes predictors of lek locations were grassland area and forest area. I also examined lek locations versus random locations at the 4.0 km buffer and by physiographic province. I modeled the Flint Hills and found an overall accuracy of 70.6% (Wilkes' $\lambda = 0.798$, $F_{2,683} = 86.546$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 83.1% of the time, but misclassified random locations as lek locations 42.0% of the time. Two cover classes were found to be strong predictors of lek locations in the Flint Hills (Table 7). In the Flint Hills region, lek locations had significantly more grassland area (ha) ($F_{1,684} = 157.627$, $P < 0.001$) than random locations, which had more cropland area (ha) ($F_{1,684} = 117.516$, $P < 0.001$) (Fig. 29).

Fig. 29. Comparison of lek location versus random location mean area of a) forest, grassland and cropland and b) urban and water within the 4.0 km buffer for the Flint Hills.

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Grassland
Cropland

b)


100
80
60
40
20
0
Mean Area (ha)
Lek
Random
Location Type
Urban
Water

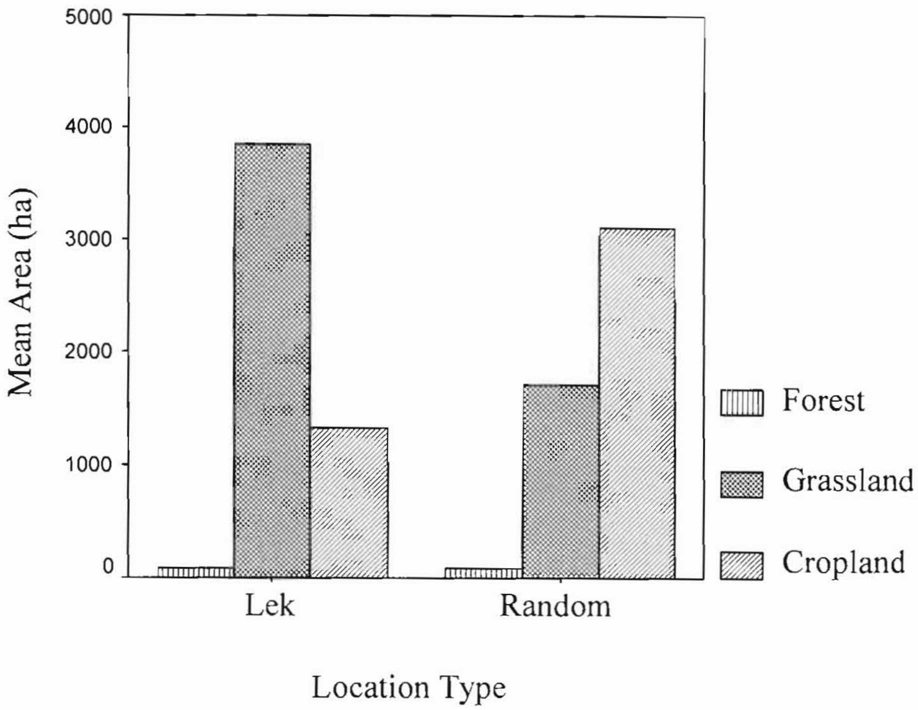
The Smoky Hills model had an overall accuracy of 85.6% (Wilkes' $\lambda = 0.486$, $F_{3,400} = 140.994$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 95.0% of the time, but misclassified random locations as lek locations 23.8% of the time. The model found 3 cover classes within the 4.0 km buffer as predictors of lek locations (Table 7). Lek locations in the Smoky Hills had significantly more grassland area (ha) ($F_{1,402} = 377.590$, $P < 0.001$) and water area (ha) ($F_{1,402} = 20.890$, $P < 0.001$) than did random locations (Fig. 30).

The Osage Cuestas model had an overall accuracy of 76.3% (Wilkes' $\lambda = 0.709$, $F_{3,372} = 50.845$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 91.0% of the time, but classified random locations incorrectly as lek locations 28.3% of the time. Three cover classes in the 4.0 km buffer were predictors of lek locations (Table 7). Random locations had significantly more forest ($F_{1,374} = 116.163$, $P < 0.001$) and urban area ($F_{1,374} = 18.254$, $P < 0.001$) than lek locations (Fig. 31). The Glaciated Region had an overall model accuracy of 73.7% (Wilkes' $\lambda = 0.765$, $F_{3,148} = 15.317$, $P < 0.001$). The discriminant function analysis correctly predicted random locations 78.9% of the time, but misclassified lek locations as random 31.6% of the time. The model found 3 cover classes that were predictors of lek locations (Table 7). Random locations had significantly more area of forest ($F_{1,150} = 18.286$, $P < 0.001$) and cropland ($F_{1,150} = 21.317$, $P < 0.001$) than did lek locations (Fig. 32).

Traditional Lek Locations Versus Temporary Lek Locations.—At the 4.0 km buffer scale I also examined traditional versus temporary leks. The overall accuracy for the combined area was 46.1% (Wilkes' $\lambda = 0.995$, $F_{1,807} = 4.215$, $P = 0.04$). The

Fig. 30. Comparison of lek location versus random location mean area of a) forest, grassland, and cropland and b) urban and water within the 4.0 km buffer the Smoky Hills.

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Grassland
Cropland

b)

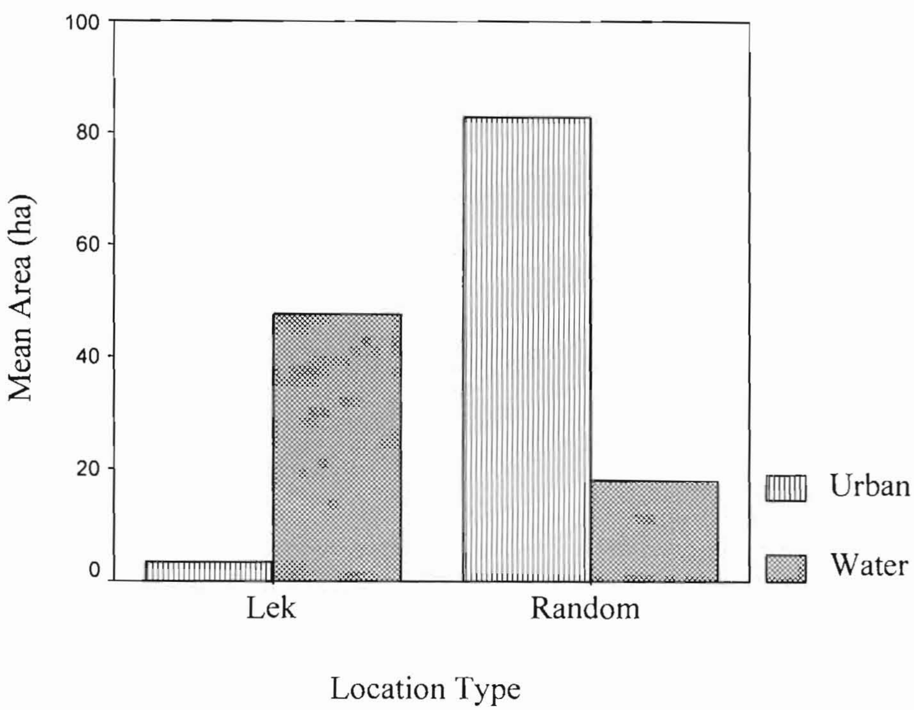
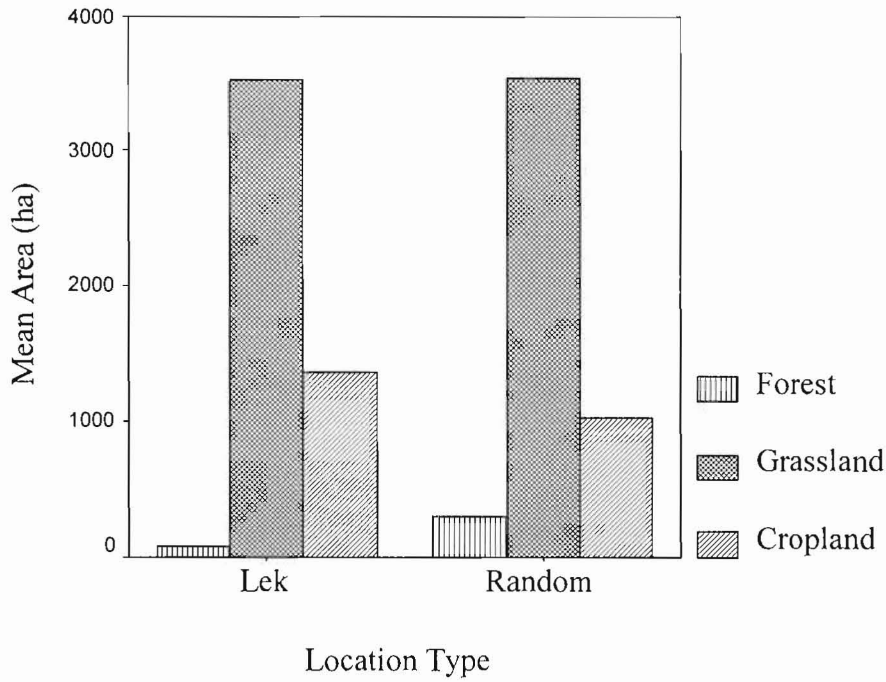

100
80
60
40
20
0
Mean Area (ha)
Lek
Random
Location Type
Urban
Water

Fig. 31. Comparison of lek location versus random location mean area of a) forest, grassland, and cropland and b) urban and water within the 4.0 km buffer Osage Cuestas.

a)


4000
3000
2000
1000
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Grassland
Cropland

b)

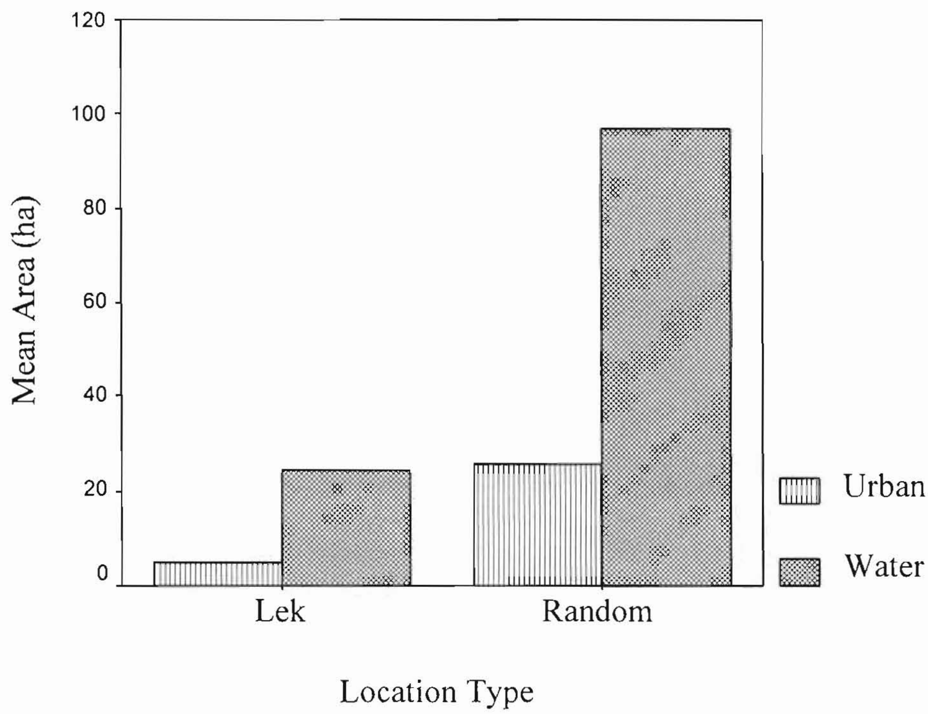
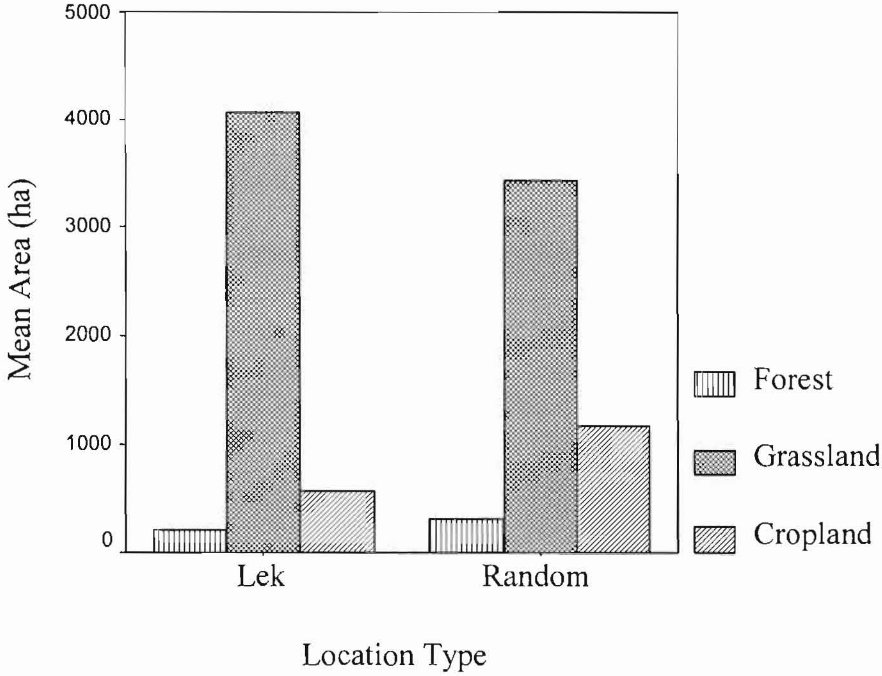
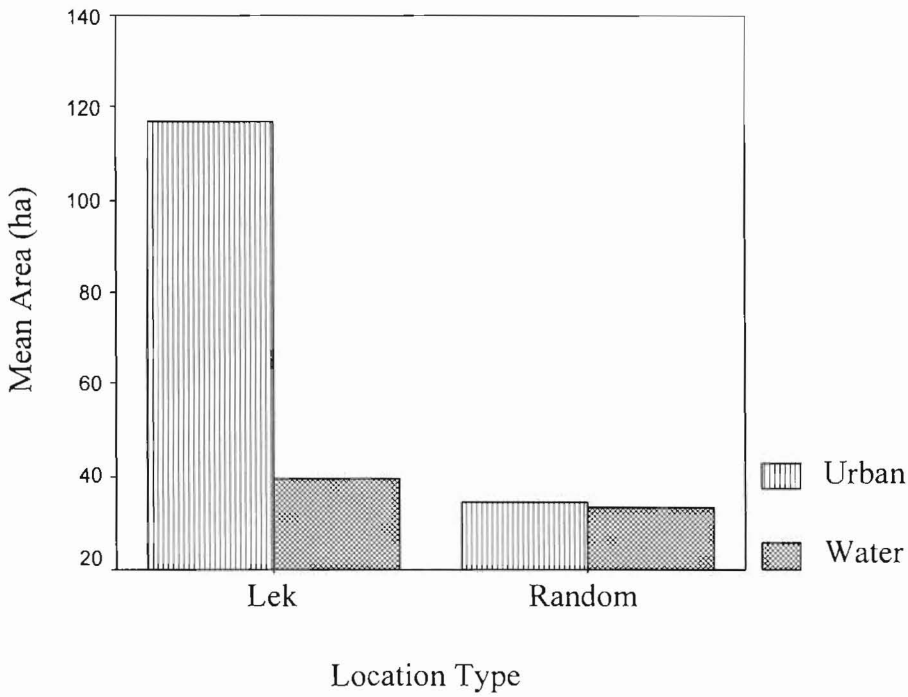

120
100
80
60
40
20
0
Mean Area (ha)
Lek
Random
Location Type
Urban
Water

Fig. 32. Comparison of lek location versus random location mean area of a) forest, grassland, and cropland and b) water and urban within the 4.0 km buffer the Glaciated Region.

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Lek
Random
Location Type
Forest
Grassland
Cropland

b)


140
120
100
80
60
40
20
Mean Area (ha)
Lek
Random
Location Type
Urban
Water

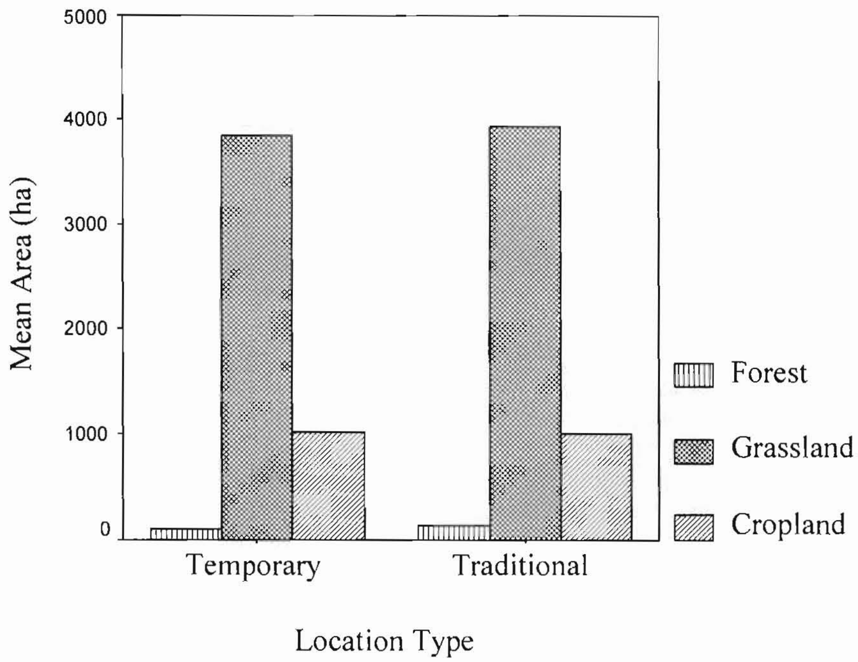
discriminant function analysis correctly classified temporary lek locations 67.7% of the time and misclassified traditional lek locations as temporary lek locations 60.7% of the time. Only 1 land cover class was a predictor of traditional versus temporary leks (Table 7). Traditional lek locations had significantly more area of forest ($F_{1,807} = 4.215$, $P = 0.04$) than temporary lek locations within the 4.0 km buffer (Fig. 33).

I also examined traditional versus temporary lek locations in the 4.0 km buffer by physiographic provinces, and that the Flint Hills model had an overall accuracy of 74.1% (Wilkes' $\lambda = 0.940$, $F_{1,341} = 21.908$, $P < 0.001$). The discriminant function analysis correctly predicted traditional lek locations 95.4% of the time, however, it misclassified temporary lek locations 85.6% of the time as traditional lek locations. Only 1 predictor of traditional versus temporary lek locations was found (Table 7). Temporary lek locations had significantly more urban area (ha) ($F_{1,341} = 21.908$, $P < 0.001$) than traditional lek locations (Fig. 34).

For the 4.0 km buffer in the Smoky Hills the model had an overall accuracy of 62.9% (Wilkes' $\lambda = 0.912$, $F_{2,199} = 9.627$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 65.1 % of the time, but misclassified temporary lek locations as traditional locations 42.9% of the time. Two cover classes were predictors of traditional versus temporary lek locations (Table 7). Traditional lek locations had significantly more forest area (ha) ($F_{1,200} = 11.626$, $P = 0.001$) than temporary locations (Fig. 35).

The Glaciated Region model had an overall accuracy of 65.8% (Wilkes' $\lambda = 0.938$, $F_{1,74} = 4.919$, $P = 0.03$). The discriminant function analysis correctly classified

Fig. 33. Comparison of traditional versus temporary lek location mean area of a) forest, grassland, and cropland and b) urban and water within the 4.0 km buffer for all leks combined.


5000
4000
3000
2000
1000
0
Mean Area (ha)
Temporary
Traditional
Location Type
Forest
Grassland
Cropland

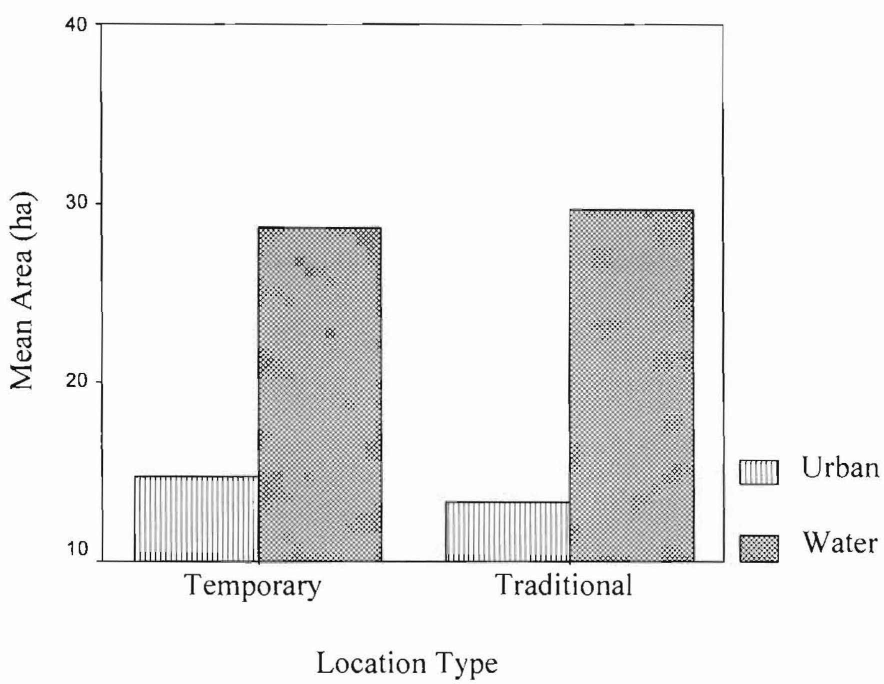
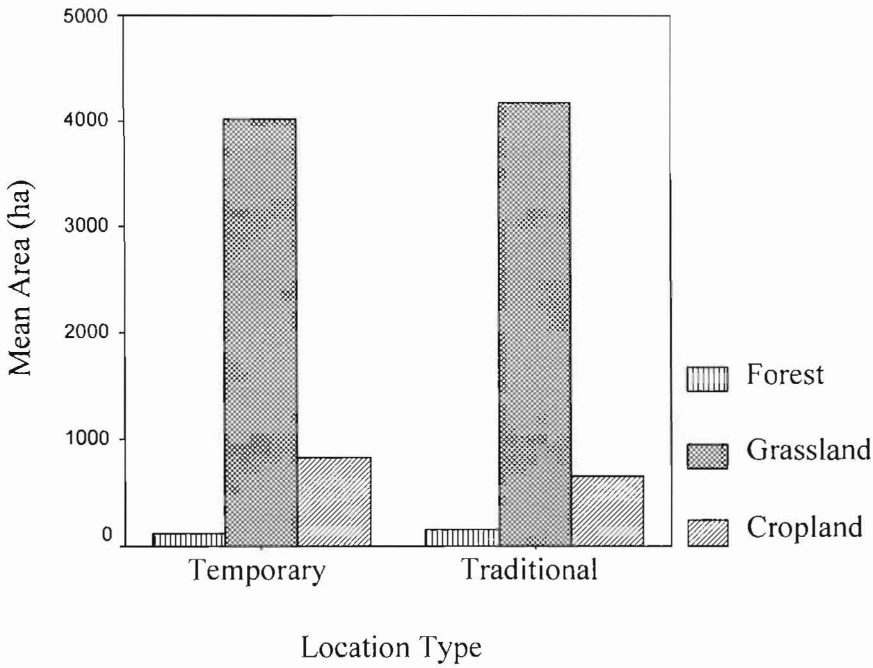

40
30
20
10
Mean Area (ha)
Temporary
Traditional
Location Type
Urban
Water

Fig. 34. Comparison of traditional versus temporary lek location mean area of a) forest, grassland, and cropland and b) urban and water within the 4.0 km buffer for the Flint Hills

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Forest
Grassland
Cropland
Temporary
Traditional
Location Type

b)

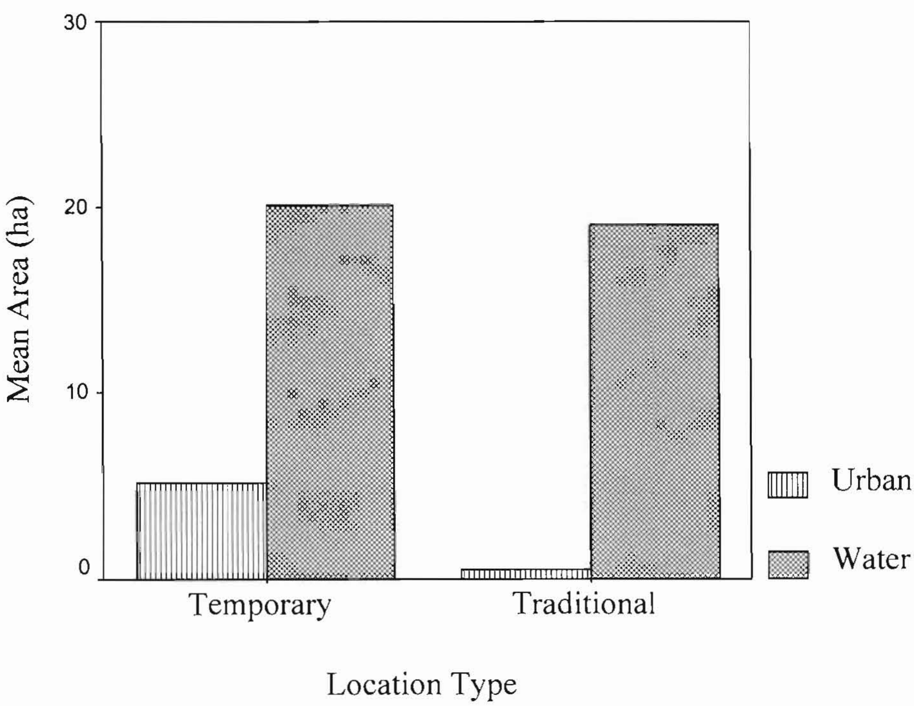
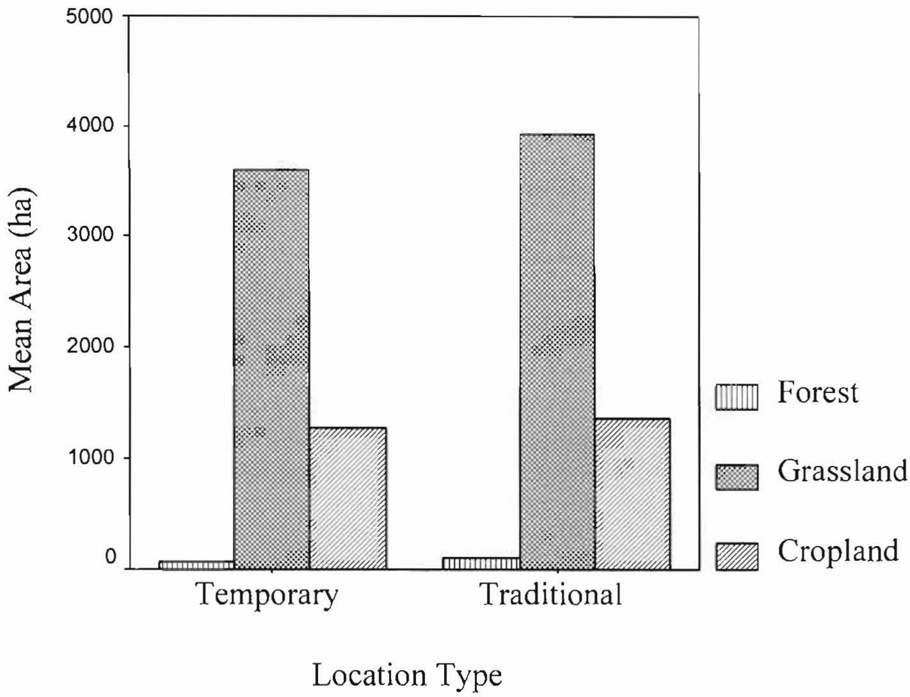

30
20
10
0
Mean Area (ha)
Urban
Water
Temporary
Traditional
Location Type

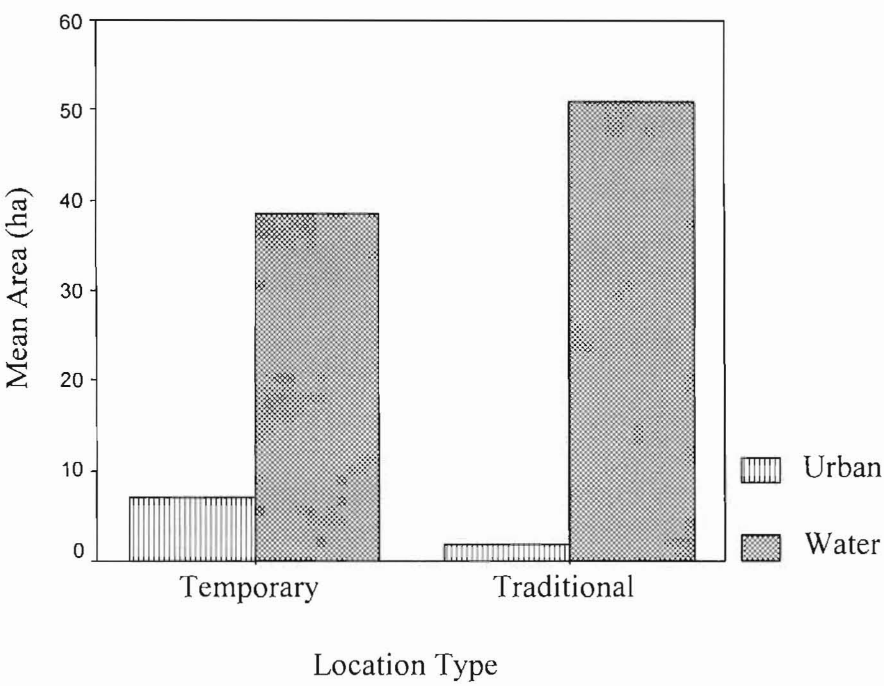
Fig. 35. Comparison of traditional versus temporary lek location mean area of a) forest, grassland, and cropland and b) urban and water with in the 4.0 km buffer for the Smoky Hills.

a)



5000
4000
3000
2000
1000
0
Mean Area (ha)
Temporary
Traditional
Location Type
Forest
Grassland
Cropland

b)



60
50
40
30
20
10
0
Mean Area (ha)
Temporary
Traditional
Location Type
Urban
Water

traditional lek locations 67.2% of the time, but misclassified temporary lek locations as traditional 40.0% of the time. Only one land cover class was a predictor of traditional lek locations (Table 7). Temporary lek locations had significantly more water area ($F_{1,74}$ = 4.919, $P = 0.03$) than traditional lek locations (Fig. 36).

One geographic region did not have any predictors of traditional versus temporary lek locations at the 4.0 km buffer scale. The Osage Cuestas had no significant predictors within the 5 land cover classes ($P > 0.05$).

Combined 1.6 km Buffer Model

All Lek Locations Versus Random Locations.—I tested the predictability of land cover, landscape metrics, and topographic features in the 1.6 km buffer. The overall combined model had an accuracy of 77.0% (Wilkes' $\lambda = 0.675$, $F_{17,1600} = 45.348$, $P <$ 0.001). The discriminant function analysis correctly classified lek locations in the 1.6 km buffer 84.7% of the time. It misclassified random locations as lek locations 15.3% of the time. Seventeen variables were predictors of lek locations (Table 8).

The combined Flint Hills model had an accuracy of 80.8% (Wilkes' $\lambda = 0.633$, $F_{7,678} =$ 56.1, $P < 0.001$). The discriminant function analysis correctly classified lek locations 94.5% of the time. However, random locations were misclassified as lek locations 32.9% of the time. The discriminant function analysis found 9 predictors of lek locations versus random locations (Table 8).

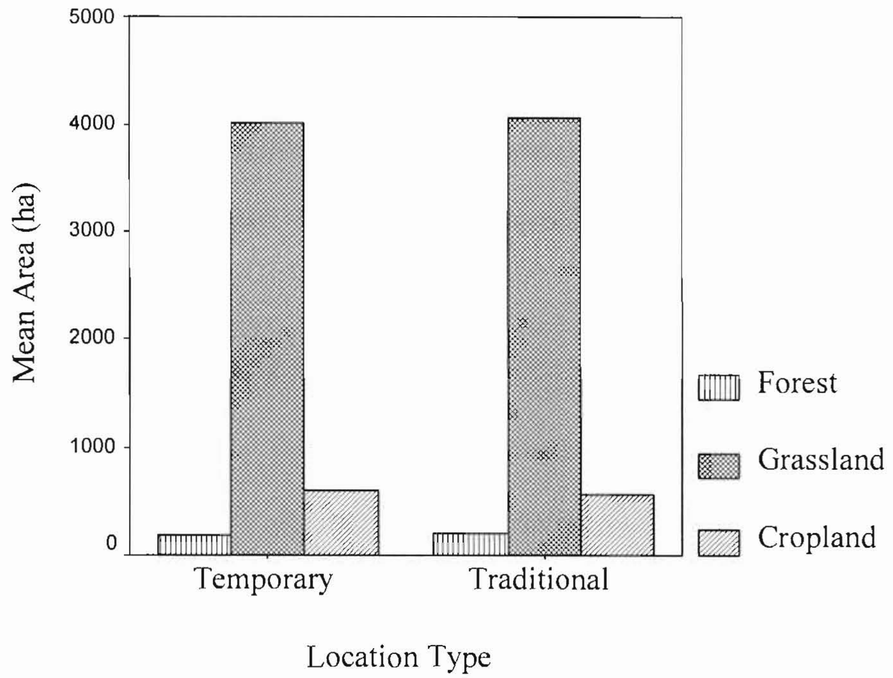
In the Smoky Hills, I found that the combined model had an accuracy of 88.9% (Wilkes' $\lambda = 0.398$, $F_{7,396} =$ 85.467, $P < 0.001$). The discriminant function correctly classified lek locations 96.5% of the time, but random locations were

Table 7. Land cover predictive models for 4.0 km buffer for lek locations versus random locations and traditional lek locations versus temporary lek locations for all areas combined and physiographic provinces. Variables are listed in order of discriminating ability from strongest to weakest.

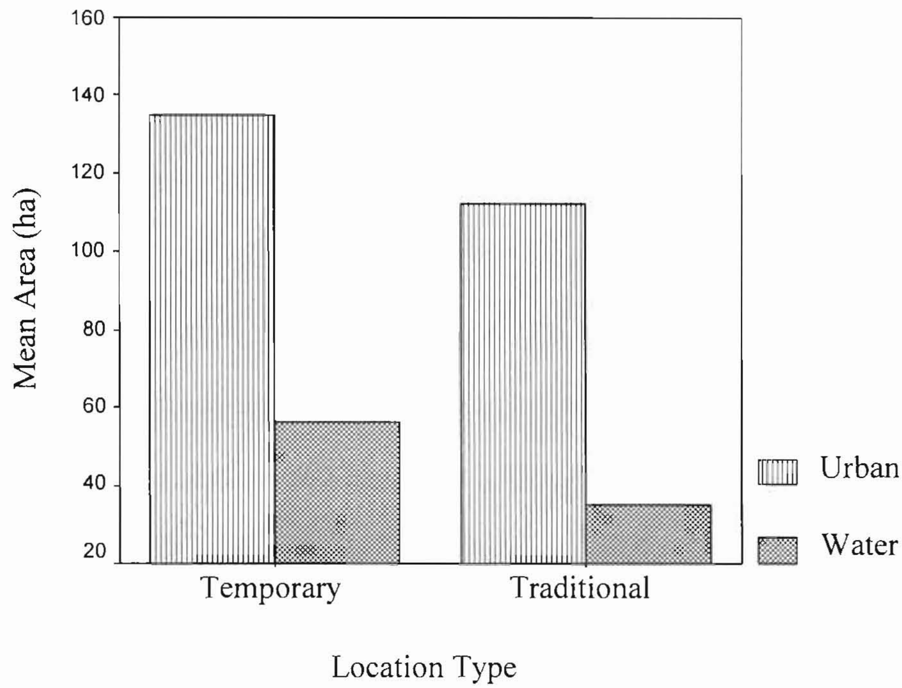
	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Overall Model	grassland area, forest area,water area	forest area
Flint Hills	grassland area and cropland area	urban area
Glaciated Region	cropland area, forest area, urban area	water area
Osage Cuestas	forest area, urban area, cropland area	No predictors
Smoky Hills	grassland area, forest area, water area	forest area, urban area

Fig. 36. Comparison of traditional versus temporary lek location mean area of a) forest, grassland and cropland and b) urban and water within the 4.0 km buffer for the Glaciated Region.

a)


5000
4000
3000
2000
1000
0
Mean Area (ha)
Forest
Grassland
Cropland
Temporary
Traditional
Location Type

b)


160
140
120
100
80
60
40
20
Mean Area (ha)
Urban
Water
Temporary
Traditional
Location Type

misclassified as leks 19.3%. Seven variables were predictors of leks (Table 8).

The combined Osage Cuestas model had an accuracy of 87.0% (Wilkes' λ = 0.513, $F_{7,368}$ = 49.873, $P < 0.001$). The discriminant function analysis correctly classified lek locations 92.0% of the time. However, it misclassified random locations as lek locations 18.1% of the time. Seven variables were predictors of lek locations versus random locations (Table 8).

The combined model for the Glaciated Region had an accuracy of 87.5% (Wilkes' λ = 0.435, $F_{6,145}$ = 31.426, $P < 0.001$). The discriminant function analysis correctly classified lek locations 96.1%. Random locations were misclassified as lek locations 21.1% of the time. Six variables were predictors of lek locations (Table 8).

Traditional Lek Locations Versus Temporary Lek Locations.—I tested a combined model of land cover area, landscape metrics, and topographic features for traditional versus temporary leks. The combined model for the study area had an overall accuracy of 67.6% (Wilkes' λ = 0.927, $F_{4,804}$ = 15.745, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 74.9%, but misclassified temporary lek locations as traditional 55.4%. Four variables were predictors of traditional versus temporary lek locations (Table 8).

I also tested a combined model for the 4 physiographic provinces. The Flint Hills had an model accuracy of 63.0% (Wilkes' λ = 0.939, $F_{4,338}$ = 5.465, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 63.6 % of the time. Temporary lek locations however were misclassified as traditional lek locations 38.9% of the time. Four variables were predictors of traditional lek locations (Table 8).

The combined Smoky Hills region had an accuracy of 75.2% (Wilkes' $\lambda = 0.783$, $F_{4,197} = 13.642$, $P < 0.001$). The discriminant function analysis was able to correctly classify traditional lek locations 78.1% of the time, but misclassified temporary lek locations as traditional 32.1%. Four variables were found to be predictors of traditional versus temporary lek locations (Table 8).

When I tested the Osage Cuestas, the combined model had an accuracy of 71.8% (Wilkes' $\lambda = 0.899$, $F_{2,185} = 10.734$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 77.9% of the time. However, it misclassified temporary lek locations as traditional 55.9% of the time. Two predictors of traditional lek locations were found (Table 8).

For the Glaciated Region, the combined model had an accuracy of 96.1% (Wilkes' $\lambda = 0.371$, $F_{8,67} = 14.206$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 98.4% of the time. Temporary lek locations were misclassified 13.3% of the time. Eight variables were predictors of lek locations (Table 8).

Combined 4.0 km Buffer Model

All Lek Locations Versus Random Locations.—In the 4.0 km buffer I also developed a model, which used both land cover and topographic features to determine which would be more accurate at predicting lek locations. The model of all areas combined had an overall accuracy of 70.6% (Wilkes' $\lambda = 0.789$, $F_{3,1614} = 144.288$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 77.8% of the time. The model however misclassified random locations as lek locations 36.5% of the

Table 8. Combined predictive models for 1.6 km buffer for lek locations versus random locations and traditional lek locations versus temporary lek locations for all areas combined and physiographic provinces. Variables are listed in order of discriminating ability from strongest to weakest.

	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Overall Model	grassland area, mean greassland patch size, mean grassland area weighted shape index, mean grassland patch edge, cropland area, mean cropland area weighted shape index, forest area, elevation, mean forest perimeter area ratio, mean grassland perimeter area ratio, mean cropland perimeter area ratio, mean cropland area weighted patch fractal dimension, mean forest edge, forest edge density, grassland edge density, mean grassland shape index, median grassland patch size	forest area, slope, forest total edge, number of forest patches
Flint Hills	grassland area, elavation, mean grassland area weighted shape index, mean cropland area weighted shape index, mean grassland perimeter area ratio, mean forest patch edge, grassland edge density	mean forest shape index, number of forest patches, water area, grassland area
Glaciated Region	mean grassland patch fractal dimension, elevation, cropland area, mean cropland patch fractal dimension, slope, mean grassland patch edge	mean forest area weighted shape index, forest edge density, forest area, mean grassland patch fractal dimension, mean grassland patch edge, mean grassland perimeter area ratio, number of cropland patches, cropland edge density

Table 8. continued.

	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Osage Cuestas	forest edge density, mean forest patch fractal dimension,cropland edge density, urban area, forest area, elevation, cropland area	forest area, slope
Smoky Hills	mean grassland area weighted patch fractal dimension, grassland area, mean greassland patch edge, forest area, median grassland patch size, grassland edge density, mean greassland patch fractal dimension	forest area, slope, mean forest patch size, mean patch fractal dimension

time. Three variables were predictors of lek locations (Table 9).

The Flint Hills' combined model had an accuracy of 76.1% (Wilkes' $\lambda = 0.741$, $F_{2,683} = 119.592$, $P < 0.001$). The discriminant function analysis correctly classify lek locations 86.9% of the time, but misclassified random locations as lek locations 34.7% of the time. Two variables were predictors of lek locations (Table 9).

The Smoky Hills' combined model had an accuracy of 85.6% (Wilkes' $\lambda = 0.486$, $F_{3,400} = 140.994$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 95.0% of the time. Random locations were misclassified as lek locations 23.8% of the time. Three variables were found to be predictors of lek locations (Table 9).

The Osage Cuestas combined model had an accuracy of 85.1% (Wilkes' $\lambda = 0.587$, $F_{4,371} = 65.191$, $P < 0.001$). The discriminant function analysis correctly classified lek locations 96.8% of the time. However, it misclassified random locations as lek locations 26.6% of the time. Four variables were predictors of lek locations (Table 9).

The Glaciated Region had an overall model accuracy of 74.3% (Wilkes' $\lambda = 0.707$, $F_{4,147} = 15.225$, $P < 0.001$). The discriminant function analysis correctly classified random locations 80.3% of the time, but misclassified lek locations as random 31.4% of the time. Four variables were predictors of random locations (Table 9).

Traditional Lek Locations Versus Temporary Lek Locations.—In the 4.0 km buffer I also tested land cover and topographic features. The overall model had an accuracy of 61.9% (Wilkes' $\lambda = 0.951$, $F_{3,805} = 13.891$, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 65 % of the time.

Temporary lek locations were misclassified as traditional 47.7% of the time. Three variables were predictors of traditional lek locations (Table 9).

The combined model for the Flint Hills had an accuracy of 74.1% (Wilkes' λ = 0.940, $F_{1,341}$ = 21,908, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 95.3% of the time. However, temporary lek locations were misclassified as traditional leks 85.6% of the time. Only one variable was a predictor of traditional lek locations (Table 9).

The combined model for the Smoky Hills had an accuracy of 68.8% (Wilkes' λ = 0.808, $F_{4,197}$ = 11.676, $P < 0.001$). The discriminant function analysis correctly classified traditional lek locations 69.2% of the time. Temporary lek locations were misclassified as traditional lek locations 32.1% of the time. Four variables were predictors of traditional lek locations (Table 9).

The combined model for the Osage Cuestas had an overall accuracy 67.6% (Wilkes' λ = 0.939, $F_{1,186}$ = 11.985, P = 0.001). The discriminant function analysis correctly classified traditional lek locations 76.0% of the time. However, temporary lek locations were misclassified 29.4% of the time. Only one variable was a predictor of traditional versus temporary lek locations in the Osage Cuestas (Table 9).

The Glaciated region had an overall model accuracy of 65.8% (Wilkes' λ = 0.938, $F_{1,74}$ = 4.919, P = 0.02). The discriminant function analysis correctly classified traditional lek locations 67.2% of the time. Temporary lek locations, however, were misclassified as traditional 40% of the time. Only one variable was a predictor of traditional lek locations (Table 9).

Table 9. Combined predictive models for 4.0 km buffer for lek locations versus random locations and traditional lek locations versus temporary lek locations for all areas combined and physiographic provinces. Variables are listed in order of discriminating ability from strongest to weakest.

	All Lek Versus Random Location Predictors	Traditional Lek Versus Temporary Lek Predictors
Overall Model	grassland area, elevation, forest area	slope, grassland area, forest area
Flint Hills	grassland area, elevation	urban area
Glaciated Region	cropland area, forest area, elevation, urban area	water area
Osage Cuestas	elevation, cropland area, urban area, forest area	slope
Smoky Hills	grassland area, water area, cropland area	forest area, elevation, grassland area, slope

DISCUSSION

Topographic Model

All Lek Locations Versus Random Locations.—The topographic model comparing lek versus random locations for all areas combined was not a very accurate model. I found no other studies that could be used to compare with my findings for the topographic models. Therefore, I can only make general statements as to why these models may or may not have been very accurate. One reason for the general inaccuracy of most of the topographic models for both lek locations versus random locations and traditional versus temporary lek locations may have been the level and scale of the data that were collected and analyzed. The topographic models may not have been very accurate because greater prairie-chickens may be selecting topographic features at a much smaller scale than expected and could be measured with DEMs. Also, vegetation density at the local or pasture level may have a greater effect on lek locations than topography. Horak (1985) found that greater prairie-chicken leks are often located on elevated sites where the vegetation is thin due to cattle grazing or thin soils.

Comparing the mean elevation of lek locations to random locations for each model, showed that lek locations were at higher elevations than random locations. Lek locations in the Chautauqua Hills, Flint Hills, Glaciated Region, and Osage Cuestas had lek location mean elevations that were greater than the mean elevation for each province. This probably means that in these provinces greater prairie-chickens were selecting elevations higher than the surrounding terrain.

The overall model was one of the least accurate models. In this model, lek locations were positively associated with elevation but negatively associated with slope.

The model at this level probably was not very accurate because of all the variation in elevation and slope of the 5 physiographic provinces used in the topographic features model. It also may not have been very accurate because the large area it encompassed provided numerous high elevations for greater prairie-chickens to use as lekking sites.

The topographic models for the 5 physiographic provinces were all similar to the overall model because elevation and slope were predictors for 4 of the 5 provinces. The models in each of these regions were slightly more accurate than the overall model. This suggests that the overall model was less accurate due to the variation in elevation and slope from the 5 physiographic provinces being combined into one model. Provinces that covered more area, Flint Hills, Smoky Hills, and Osage Cuestas, often considered the core of the greater prairie-chicken range in Kansas, may have been less accurate because in these areas elevation and slope may not have been limiting factors for lek locations. The 2 provinces that covered the least surface area, Chautauqua Hills and Glaciated Region, had more accurate models. The improved accuracies for these 2 provinces may be due to these areas having elevation as a possible limiting factor for greater prairie-chickens lek locations.

The Glaciated Region model was the only model that had one predictor for lek locations versus random locations. This probably was because there was only one route in the province. The single route covered a small area at the southeast corner of the Glaciated Region. The model for this province would only be of value in predicting lek locations for a small area of that province.

Traditional Lek Locations Versus Temporary Lek Locations.—I found that for traditional versus temporary lek locations, topographic features for the most part were not very good predictors, although the overall model for traditional versus temporary lek locations was slightly more accurate than the overall model for predicting lek locations versus random locations. Again, the large variation in topography for all of the physiographic provinces being combined into a single model probably reduced its accuracy.

The 5 physiographic provinces had varying model accuracy as well as variability in the topographic features that were predictors of traditional versus temporary lek locations. For the most part elevation, came out as the predictor of traditional lek locations. The 3 largest provinces, the Flint Hills, Smoky Hills, and Osage Cuestas, had low model accuracies. Again this was possibly because elevation was not a limiting factor for traditional lek locations in these provinces.

The Chautauqua Hills had the greatest model accuracy, but interestingly it also had a second predictor, aspect. Elevation and aspect may possibly be limiting factors for traditional lek locations in this province. This may also be due to some other factor such as land cover, which was affected by elevation and aspect in this province. McCombs (1997) used topographic features to predict northern flying squirrel (*Glaucomys sabrinus*) locations in Virginia. He found it to be an accurate and effective method for predicting their locations due to slope, aspect, and elevation effects on soils and moisture that in turn affect vegetation.

The Glaciated Region did not have high model accuracy and was probably not a good model because it lacked repetition within the Glaciated Region. This made the model only good at predicting traditional versus temporary lek locations within a single area that was located in the southeastern corner of the province.

Land Cover 1.6 km Buffer Model

All Lek Locations Versus Random Locations.—The results of my 1.6 km buffer land cover model were similar to other studies, including investigations at the local as well as the landscape level (Christisen 1981, Cartwright 2000, Neimuth 2000). The overall model had land cover classes that one would expect to be predictors of lek locations. This means that leks were in large grassland complexes with little or no cropland and very little forest. This was true in each province where large grassland areas were a predictor of lek locations. To determine percent cover of grassland found by Merrill et al. (1999) for Minnesota, I combined grassland cover, Conservation Reserve Program land, grassland-shrub, wetland, and grassland and found grassland percent cover to be 41.1%. In Kansas, I found that within the same sized buffer area as Merrill et al. (1999), the overall grassland percent cover for lek locations was twice that of Minnesota, at 82.8%.

In 2 provinces, the Smoky Hills and the Glaciated Region, water area was a predictor of lek locations. This was probably because in the Smoky Hills there are a large number of stock ponds located within the grassland complexes, and many of the random locations were associated with large cropland areas, which lacked these stock ponds. Also, a single route in the Smoky Hills was located relatively close to a large reservoir. Within the Glaciated Region, there was only one survey area and it was located in close proximity to a large power plant, which contains several large cooling lakes.

For all provinces but one, lek locations were associated negatively with forest area. In these areas lek locations were often associated with small amount of forest area.

This was similar to the results of Merrill et al. (1999), who also found lek locations associated with a smaller amounts of forest cover in Minnesota. The Smoky Hills province was the only province positively associated to forest area and in which leks were associated with larger amounts of forest cover. Biologically speaking one would not expect to find greater prairie-chickens associating with large amounts of forest cover; these areas contain perches for avian predators and are corridors for mammalian predators (Hamerstrom et al. 1957, Newell et al. 1987). The most likely reason for this association was that several survey areas in the province had forested riparian areas.

The Osage Cuestas was another province where the model did not seem to fit biologically. Lek locations were associated negatively with grassland area, and positively with cropland area. This was probably because the area has large amounts of native tallgrass prairie that has been converted to cropland and exotic cool season grasses. Thus, lekking sites may be limited and forcing birds to lek on cropland rather than grass as well as fragmenting the populations similar to the situation in Missouri, Illinois, Minnesota, Wisconsin, and Oklahoma (Svedarsky et al. 2000). Also, exotic cool season grasses may have caused confusion in the classification of grassland areas because cropland areas and to cool season grasses having a similar satellite signature to cropland.

Traditional Lek Locations Versus Temporary Lek Locations.—I found that 3 models developed for traditional versus temporary lek locations had forest area as a predictor of traditional lek locations. For the overall model, the Smoky Hills and the Osage Cuestas traditional lek locations were associated with smaller amounts of forest area than were temporary lek locations. This was probably because as reported previously (Hamerstrom et al. 1957, Newell et al. 1987), greater prairie-chickens avoided these areas due to possible greater predation rates. Also traditional lek locations are those sites that are there year after year and where birds are more likely to congregate, and temporary lek locations are those areas that are less suitable, it would be possible that temporary lek locations were located closer to forest.

The model of the Flint Hills, however, incorporated grassland and water area as predictors of traditional lek locations. In this area, traditional leks were positively associated with grassland area and negatively associated with water area. In much of the Flint Hills, stock ponds are built in small valleys running between hilltops. In the previous section on topographic features, I noted traditional lek locations were often located at higher elevations and temporary leks were at lower elevations. This could explain why temporary lek locations were often associated with more water area. Temporary lek locations were located at the lower elevation and therefore closer to the stock ponds located within the small valleys.

Landscape Metrics Model

All Lek Locations Versus Random Locations.—Alone, landscape metrics were slightly poorer predictors of lek locations versus random locations than was land cover area. Merrill et al. (1999) only examined 2 landscape metrics: patch size and patch shape. They did not, however, test the power of these landscape metrics in predicting lek locations. Landscape metrics have been used to examine the occurrence of other bird species and population trends with relatively good success (Pogue 1998, Schairer 1999).

In all but 1 model for my study at least a couple of grassland metrics were found to be predictors for separating lek locations and random locations. The Osage Cuestas model used forest and cropland metrics for separating lek locations from random locations. This was probably because the landscape within the Osage Cuestas is highly fragmented by forest and cropland.

In all areas where mean grassland patch size was a predictor, leks had significantly larger grassland patches than random locations. Merrill et al. (1999) also found that leks had significantly larger grassland patch sizes. However, patch sizes in Minnesota were significantly smaller than those in any of the 4 provinces I studied for the land cover and landscape metrics. Mean patch size in Minnesota for all leks was 22.1 ha (Merrill et al 1999). In Kansas, mean patch size ranged from 372.4 ha in the Smoky Hills to 624.2 ha in the Glaciated Region. Unlike Merrill et al. (1999), I did not measure patch size if it extended beyond the 1.6 km buffer. Therefore, probably the grassland patch sizes in Kansas are much larger than I calculated. Although I used satellite imagery and Merrill et al. (1999) used black and white aerial photos, the patch size difference is so great that even this difference in mapping techniques could not have had that great an effect.

Traditional Lek Locations Versus Temporary Lek Locations.—For the overall model and the Flint Hills model, landscape metrics were not very accurate at predicting traditional lek locations versus temporary lek locations. Both models had mean forest patch edge as a predictor of traditional lek locations, but were only able to correctly classify traditional lek locations slightly more than 50% of the time. This low accuracy in predicting traditional versus temporary lek locations was probably because of the difficulty in classifying lek locations as traditional or temporary. Also at the fine scale grassland quality may have a greater affect.

Discriminant function analysis for the Smoky Hills found that traditional lek locations were predicted by using a landscape metric associated with forest patches, probably because of the locations of the survey areas and the amount of small riparian forest running through several of the areas. Greater prairie-chickens have been shown to avoid these areas for lekking (Merrill et al. 1999).

Both the Osage Cuestas and the Glaciated Region models contained landscape metrics that predicted traditional versus temporary lek locations, but in both cases there were no significant differences between the 2 lek type locations for these landscape metrics. These metrics probably are not major biological predictors of traditional lek locations but more an artifact of the discriminant function analysis.

Land Cover 4.0 km Buffer Model

All Lek Locations Versus Random Locations.—My findings showed that as the size of the buffer increases away from the lek locations the accuracy of the model begins to drop. Therefore, the best area for predicting and managing greater prairie-chicken lek locations is probably less than 4.0 km. When examining both the 1.6 km and 4.0 km models, the overall model, the Flint Hills model, and the Smoky Hills model all found grassland area a consistent predictor of lek locations. For the overall model, forest area and water area were all associated with random locations. However, the Smoky Hills model also had forest area and water area as predictors of leks.

Larger forest and urban areas were associated with random locations within the Osage Cuestas. However, the model also found cropland to be a predictor, but instead of random locations being associated with large cropland area, it was lek locations. This also may have to do with the fact that in the Osage Cuestas the grassland quality or quantity is not adequate for lekking, therefore males may be selecting lek within cropland areas. Also, as previously mentioned, this could be because large areas have been converted from native prairie to cropland and exotic cool season grass. The exotic cool season grasses are often hard to separate from cropland by satellite image due to similar signatures.

The Glaciated Region model found lek locations associated with large amounts of urban area. This was probably again due to there being only one survey area located in the southwestern corner of the province. The Glaciated Region survey area was within 2 km of a large power plant which I classified an urban area.

Traditional Lek Locations Versus Temporary Lek Locations.—The overall model at 4.0 km was not good for predicting traditional versus temporary leks. The model had an overall accuracy < 50%. The model probably had a low accuracy because at the 4.0 km level there was a lot of land cover overlap between traditional lek locations and temporary lek locations. Once again, traditional lek locations within the Smoky Hills were associated with larger amounts of forest most likely due to locations of several of the survey areas within the province being located to forested riparian areas.

The discriminant function analysis for the Glaciated Region found water area be a of temporary lek locations, but was probably because the survey area was located in the southwestern corner of the province with no repetition elsewhere. Also traditional lek locations were often located on the north side of the lek survey route away from the power plant and its cooling lakes. The temporary leks were often located on the south side of the route closer to the power plant and its cooling lakes.

Combined 1.6 km Buffer Model

All Lek Locations Versus Random Locations.—The combined model contained land cover, landscape metrics, and topographic features. The topographic features added a local scale to the model as these features were tied directly to the lek location itself and not to the buffer. The overall model contained a mixture of all 3 previous models. All models improved in their ability to predict lek locations. For the most part lek locations could be predicted by physiographic province between 91% and 97% accuracy. Overall model accuracy did not improve, probably because the random locations often were identified as lek locations. In Kansas, habitat suitable for greater prairie-chickens makes up much of the eastern part of the state, which made it virtually impossible to survey all areas which could contain lek locations within the state. Possibly, some of the random locations that were misclassified as lek locations in the model may have been correctly identified. The addition of all 3 landscape features to the model indicated that land cover was a major predictor of lek locations and also the arrangement of the land cover was based on the predictability of the landscape metrics. In all but 1 model grassland cover and grassland metrics were major predictors of lek locations. This showed that in Kansas the grassland area is closely associated with lek location, which was not surprising because greater prairie-chickens are tied so closely to the grasslands.

Traditional Lek Locations Versus Temporary Lek Locations.—I found that the combined models for traditional versus temporary lek locations did improve the accuracy of the overall model and improved the 4 physiographic province models slightly. As in each of the previous models for traditional versus temporary lek locations, the same variables were selected. The overall, Smoky Hills, and Osage Cuestas models had slope as a predictor of traditional lek locations. This again showed that adding a variable, that was at a local scale, lek location slope, improved the model. The only model, that did not have landscape metrics associated with it was the Osage Cuestas model. This was surprising because it was the area that was the most fragmented by agricultural fields and forest.

Combined 4.0 km Buffer Model

All Lek Locations Versus Random Locations.—The combined models in the 4.0 km buffer consisted of both land cover and topographic features. This combination of variables allowed the accuracy of 4 models to increase slightly. Only the Smoky Hills model did not change from the 4.0 km land cover model. The other models incorporated elevation into each model. The overall model had elevation added and water area removed from the model. The Flint Hills model had cropland removed from the model and replaced by elevation as a predictor. The Osage Cuestas and the Glaciated Region had elevation added and the discriminating power of variables from the 4.0 km model lowered.

Traditional Lek Locations Versus Temporary Lek Locations.—The combined 4.0 km models for traditional versus temporary lek locations for 3 of the 5 models had a slight increase in overall predictive power. Two models did not change with the addition of topographic features to the number of possible variables. The Flint Hills and Glaciated Region models both remained the same as the previous 4.0 km land cover model. The Osage Cuestas model, which did not have any significant variables in the previous 4.0 km land cover model, found slope to be a predictor separating traditional and temporary lek locations. This was also found in the topographic model. Both the overall model and the

Smoky Hills model had the addition of topographic features as well as changes in land cover variables.

CONCLUSIONS

The greater prairie-chicken population has been showing declines in much of its range (Svedarsky et al. 2000). Throughout the range, these declines are due to habitat fragmentation and the loss of critical native grasslands. My research showed that lek locations in Kansas were often associated with a larger grassland areas than previously reported by researchers in other parts of the greater prairie-chicken range (Hamerstrom et al. 1957, Arthraud 1968, Christisen 1981). Lek locations in Kansas were associated with grassland area from 350 ha to as much as 750 ha of grassland within the 1.6 km buffer. Ryan et al. (1998) found that greater prairie-chickens in southwestern Missouri had higher nesting success when grasslands were available in large blocks. The large blocks of grassland in Kansas normally are not managed specifically for greater prairie-chickens like they are in areas such as Missouri and Illinois.

The Osage Cuestas and the Glaciated Region showed similar trends in populations and habitat loss as areas in Missouri, Illinois, Wisconsin and Minnesota (Svedarsky et al. 2000). Merrill et al. (1999) were surprised that grassland proportion was not a predictor of lek location in Minnesota. I found in the all models grassland area as a predictor of lek locations. However, the Osage Cuestas model had grassland area as a predictor of lek locations, but its discriminating ability was less than cropland and urban area. As the grassland patch size decreases, greater prairie-chickens could begin to become isolated in this province and suffer the loss of genetic diversity and declines in nesting success similar to those found in Illinois (Westemeier et al. 1998). Fortunately, at this time, the grasslands in the Osage Cuestas are still larger than those found in Minnesota and Illinois. If care is not given to the Osage Cuestas, it soon may decline as in Missouri, Illinois, Wisconsin, Oklahoma, and Minnesota in terms of greater prairie-chicken populations (Svedarsky et al. 2000).

In the Flint Hills and Smoky Hills provinces, grassland area did not seem to be a limiting factor for greater prairie-chickens at the landscape scale. However, the greater prairie-chicken population in Kansas is still declining in most areas, and it is likely due to land management practices and poor quality grasslands rather than a lack of grassland (Applegate and Horak 1999). Kirsch (1974) suggested that annually grazing and haying greatly affected greater prairie-chicken nesting and brooding habitat quality. Unfortunately the landscape scale does not allow one to examine grassland quality at the local level. More research needs to be conducted at multiple scales on both male and female greater prairie-chicken habitat use throughout the year. More research needs to be conducted on the effects of various grazing and burning schemes at the landscape level and at the local level to determine the overall effect of these different schemes on greater prairie-chicken populations.

Research needs to be conducted on spatial distribution and arrangement of leks within the landscape in an area of less fragmented grasslands. Also, movement between leks in a less fragmented area needs to be studied. This would provide a better understanding of traditional and temporary leks and their importance to the population. Information collected on a less fragmented area would allow researchers and biologists to better understand population interactions and lek configurations within the grassland complex, which is often obscured by studying fragmented systems such as Missouri, Illinois, Wisconsin, Oklahoma, and Minnesota.

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Appendix 1. Land cover map accuracy for 1992.

Raw Classification Matrix [1]

	Open Water	Forest	Cropland	Grassland
Open Water	**55**	1	0	0
Forest	0	**83**	0	1
Cropland	0	5	**149**	14
Grassland	29	11	10	**192**
Total	84	100	159	207

Percent Classification Matrix

	Open Water	Forest	Cropland	Grassland
Open Water	**65.5**	1.0	0.0	0.0
Forest	0.0	**83.0**	0.0	0.5
Cropland	0.0	5.0	**93.7**	6.8
Grassland	34.5	11.0	6.3	**92.8**
Total	100.0	100.0	100.0	100.0

1 The classification matrix is calculated from 600 ground truth points collected from black and white digital orthophotos quads (DOQ) for 1991. These ground truth points are then compared with the classified image to find the number of misclassified pixels. The overall accuracy was 87.1%.

Appendix 2. Land cover map accuracy for 2000.

Raw Classification Matrix[1]

	Open Water	Forest	Cropland	Grassland
Open Water	**21**	1	0	0
Forest	0	**40**	0	4
Cropland	1	10	**102**	14
Grassland	20	6	4	**92**
Total	42	57	106	110

Percent Classification Matrix

	Open Water	Forest	Cropland	Grassland
Open Water	**50.0**	1.8	0.0	0.0
Forest	0.0	**70.2**	0.0	3.6
Cropland	2.4	17.5	**96.2**	12.8
Grassland	47.6	10.5	3.8	**83.6**
Total	100.0	100.0	100.0	100.0

1 The classification matrix is calculated from 315 ground truth points collected in 2000. These ground truth points were then compared with the classified image to find the number of misclassified pixels. The overall accuracy was 81.0%.

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