# Biodiversity of Open Space Grasslands at a Suburban/Agricultural Interface

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# BIODIVERSITY OF OPEN SPACE GRASSLANDS AT A SUBURBAN/AGRICULTURAL INTERFACE

## PART IV

# SPATIAL FACTORS INFLUENCING SONGBIRD DISTRIBUTION ON OPEN SPACE GRASSLANDS NEAR BOULDER, COLORADO

Final Report to:

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This document comprised the Master's Thesis of Ms. Sandra Haire, completed as part of the study of biodiversity on Boulder Open Space grasslands, and submitted in partial fulfillment of the requirements for a Master of Science degree at Colorado State University, Fort Collins, Colorado.

ABSTRACT OF THESIS

SPATIAL FACTORS INFLUENCING BIRD DISTRIBUTION IN GRASSLANDS NEAR BOULDER, COLORADO

I examined the relationships between bird abundance and landscape, plot-level habitat, and spatial location factors for eight species of grassland nesting birds and five species of urban nesting birds in Open Space areas near Boulder, Colorado, USA. These areas were composed of native shortgrass, mixed grass, tallgrass, and hayfield habitats that were situated in landscapes with varying degrees of urbanization. Landscape patterns were described at five scales using a Geographic Information Systems data base derived from Landsat Thematic Mapper imagery. Bird abundance data, collected in another, ongoing study, were related to the mapped data using coordinate locations of bird sample plots.

Species' preferences for habitat types identified within the sample plots were apparent for some lowland associates [Savannah Sparrow (*Passerculus sandwichensis*), Bobolink (*Dolichonyx oryzivorus*)] and some upland associates [Horned Lark (*Eremophila alpestris*), Lark Sparrow (*Chondestes grammacus*)]. I described changes in species composition along landscape gradients of grassland types and an urban context gradient using Canonical Correspondence Analysis (CCA). All five of the suburban nesters were associated with landscapes higher in urban composition than were the grassland nesters, suggesting that these landscapes may facilitate exploitation of grasslands by

species that otherwise would not occur in grassland habitats.

Although habitat type was an important factor in determining bird abundance, landscape context explained an even greater proportion of the variability in the bird species data than habitat type when models containing landscape and habitat variables were compared using CCA. Detection of the significance of landscape pattern was scale-dependent; the importance of landscape structure was most evident at scales between 6- and 40 ha. Analysis of the importance of spatial location demonstrated a common spatial structuring between the habitat, landscape, and bird abundance data. Quantification of spatial structure led to hypotheses about unmeasured biotic and abiotic factors that create spatially coincident patterns in bird distribution and landscape characteristics. These factors include biotic interactions, such as interspecific competition, and abiotic processes, such as geomorphology, hydrology, and land use. The effects of abiotic, or environmental processes were visible in mapped land-cover patterns. Further study was recommended to clarify the role of decrease in grassland habitat and increase of urban habitat in the landscape. Additional detail in habitat type descriptions at the plot level could enable a better comparison between landscape and habitat effects.

6 ha = 15 Acres
40 ha = 99 Acres

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TABLE OF CONTENTS

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# Chapter I

## Introduction

"People wish to know how human activity influences the fascinating diversity of biological communities." (ter Braak and Verdonschot 1995)

Grasslands of the Great Plains have been advocated as the most endangered ecosystem in North America (Samson and Knopf 1994). Declines of one-third of endemic grassland bird species support that claim. Trends in Breeding Bird Survey data show among the highest declines in grassland birds of any behavioral or ecological guild in North America (Knopf 1996). The mobility, conspicuousness, and familiarity of birds make them effective indicators of environmental change, underscoring their importance in conservation efforts (Bock 1997).

The causes of declines in grassland species are undoubtedly complex, and may be linked to a number of current and historic changes in ecological processes. Prairie bird species evolved in a shifting mosaic of grassland habitats driven to a large extent by grazing disturbance (Knopf 1996). Bison (*Bison bison*) and prairie dogs (*Cynomys ludovicianus*), two of the dominant grazers, played an important role in maintaining native grassland communities. Grazing regimes have been drastically altered by reductions in prairie dog populations, replacement of bison with domestic cattle, and the restriction of grazing pressures with fences (Mutel and Emerick 1992).

Furthermore, extensive croplands and fields of non-native hay and pasture have largely replaced natural vegetation, leaving only remnants of native prairie. Fire has also been an important force in the evolution of mixed grass (Bragg and Steuter 1996) and tallgrass prairie (Steinauer and Collins 1996). The initial increase in fire with prairie settlement 150 years ago was followed by a decrease in fire as control efforts and fragmentation became prevalent (Steinauer and Collins 1996). Collectively, these changes have resulted in a system with little resemblance to historic, presettlement conditions.

Along the Front Range of the Rocky Mountains in Colorado, urbanization has resulted in further alterations to the prairie landscape (Mutel and Emerick 1992). The Front Range refers to the eastern edge of the Rocky Mountains, and the chain of urban areas along this edge, including Fort Collins, Boulder, Denver, Colorado Springs, and Pueblo. The human population of the Front Range has increased by 350,000 since 1990 (Long 1997). This dramatic increase in human activity leads to the question: What are the effects of urbanization on biological communities?

The numbers and kinds of species change along urban-rural gradients (Blair 1996, Jokimaki and Suonen 1993, Sodhi 1992). These changes may be linked to the effects of urbanization on environmental conditions such as increased concentrations of heavy metals, changes in soil moisture regimes, altered composition and abundance of soil organisms, and modified rates of nutrient cycling (Zipperer and Pouyat 1995). In addition, the frequency and type of disturbance events, including human use, change with the proximity of urban development. The invasion of non-native species and predation by domestic animals also dramatically increase in urban areas.

The objective of this study was to describe relationships between bird species abundance patterns and landscape patterns in a grassland ecosystem that is experiencing urban encroachment. The study area included the Boulder Open Space properties and their surrounding landscape in Boulder County, Colorado, USA. Specific questions addressed were: 1) What are the relative roles of landscape pattern and plot-level habitat type in determining bird abundance patterns? 2) How does the choice of spatial scale influence the identification of correlations between landscape and avian abundance and distribution? and 3) Can inferences be made regarding the importance of underlying processes by identifying patterns in bird abundance related to geographic location?

**Background**

To provide the foundation and historical context of this study, I begin with an overview of several concepts. First, I will highlight the historical progression of thinking concerning factors influencing bird community structure. Second, I will review the inclusion of spatial scale in ecological studies. Finally, I will present some background on the importance of geographical location in the study of ecology.

*Factors Influencing Community Structure*

Patterns in avian community structure may be associated with biotic processes such as interspecific competition and predation, or with abiotic processes that result in spatial heterogeneity of habitats (Wiens 1989a). Early thinking emphasized the role of interspecific competition as the main driving factor in determining avian community patterns (Ricklefs 1975, Connell 1983). Theories recognizing the importance of weather, history, disturbance, and chance events have since challenged the competition paradigm (Wiens 1989a). One alternate theory asserts that species exhibit individualistic responses to their environment, recognizing that these responses may have been influenced by competition (Gleason 1926, Andrewartha and Birch 1954, 1984). These responses are evident in many characteristics of avian community structure, such as the observed spatial heterogeneity in the bird community. Greater understanding of community structure may be gained by recognizing the relative role of each of these alternative models (Quinn and Dunham 1983).

In a generalized scheme presented by Wiens (1989a), environmental factors (e.g., climate, habitat, and food) and stochastic events (e.g., fire, climatic fluctuations), influence species-specific responses. Biotic factors, such as predation, competition, parasitism, and mutualism further modify this response, resulting in patterns of distribution and abundance. Interpretation of community patterns, following this model, requires consideration of a complex history of events, and the relative contribution of the various elements at a given point in time. In my research, I described the influence of some environmental factors (habitat type and landscape pattern) on the bird community. I also examined implications concerning unmeasured environmental and biotic factors through an analysis of geographic location effects.

*The Importance of Scale*

There has been an historical progression from viewing natural systems as homogeneous in order to simplify research (Wiens 1995) to a recognition of the importance of heterogeneity in understanding ecological processes (Kotliar 1996, Pearson et al. 1996). Definition and use of concepts such as grain and extent (Wiens 1989b, 1990, O'Neill et al. 1986) direct attention to the choice of scale parameters and lead researchers to consider the implications of those choices (Kotliar 1996). The ability to detect patterns depends on the grain, or the size of the individual units of observation, and the extent, or the area we wish to describe by sampling. By examining how patterns vary across scales, and how patterns relate to a process of interest across scales, it is possible to infer the scale at which important processes are operating. Detecting the scale at which landscape heterogeneity is measurable is crucial, because of its functional role in ecosystems (Legendre 1993).

Spatial scales are often selected because of one or more factors that may not be related to the phenomenon of interest (Meetenmeyer 1989). Furthermore, the cost and effort of creating a spatial data base may lead to the use of existing maps and map scales, and the interpretation of results is therefore constrained by the scale of available data (e.g. McGarigal and McComb 1995). Likewise, scales of aerial photography and satellite images may determine the spatial scales chosen. In some cases, the researcher may harbor a certain preference for looking at microscale versus macroscale processes and patterns (or levels in between). Such preferences may be linked to paradigms that dominate current thinking.

Although the critical relationship between scale and processes has, until recently, often been ignored (Wiens 1989a), the history of incorporating scale has long been recognized by plant ecologists. Greig-Smith (1952) used nested quadrats to characterize spatial variance as a function of plot size. Several studies in the late 1970's recognized the scale-dependence of measurement and the need to choose a scale relevant to the phenomenon of interest (Horne and Schneider 1995). These earlier studies have contributed to the progression of thinking about scale issues, leading to the current surge in interest in the subject (McIntosh 1985). Ecologists now acknowledge the integral role of scale in affecting spatial heterogeneity, a crucial component of understanding how variability affects ecological processes (Li and Reynolds 1995).

*The Importance of Location*

The role of geographical ecology and the basis and importance of geographic variation in species were emphasized among early ecologists such as Joseph Grinnell (Bock 1997). Geography focuses on places, regions, and their interconnectedness (Abler 1987), describing and explaining differences over space. Geography's contribution to ecology lies in the location-based aspects of phenomena of interest. This includes the concept that processes vary over space, and this variation is influenced by proximate locations. The perception of locations as products of processes at multiple scales is central to geography. For ecologists, knowing how the composition of the landscape varies with location provides insight into underlying processes affecting biological phenomena of interest.

Recognition of the primacy of scale and location in describing landscape heterogeneity goes hand-in-hand with increased use of information taken from maps. Maps are an essential medium for geographers, and development of innovative ways to represent geographic relationships is a current focus of the geographical sciences. Remote sensing technologies and Geographic Information Systems (GIS) *facilitate this* focus. Geographic Information Systems are computer-based tools designed to work with data collected on, above, or below the earth's surface (Laurini and Thompson 1992). Because of the emphasis on spatial data, GIS provide an increased ability and efficiency for "Seeing relationships based on geography" (Laurini and Thompson 1992, p. 19). Using spatial information systems enables ecologists to link observations on processes of interest to locations on the Earth's surface. Analysis of locational data can also lead to hypotheses regarding the importance of unmeasured influences on phenomena of interest (Borcard and Legendre 1994).

Only a subset of the total set of potential biotic and abiotic influences on community structure can be directly measured (Borcard et al. 1992). For example, biotic interactions, site history and disturbance events may be difficult to quantify. In the absence of direct measurements of these influences, there is an increasing interest in quantifying the spatial structure of the factors that can be more readily measured. Spatial structure can be used as an indirect descriptor of various processes that have generated it (Borcard and Legendre 1994), and models integrating space as a predictive variable have been used for this purpose (e.g. Legendre and Fortin 1989). Once the effects of measured biotic and abiotic variables have been removed from measures of bird community structure, the remaining variation may be explained (at least in part) by spatial variation. In this study, I used a model that included geographic location of sample sites to provide a surrogate measure of the influence of unmeasured processes on the bird community.

# Chapter II

## Methods

Several types of data were needed to achieve the goals of this study (Appendix 2). First, information on the abundance of bird species of interest was required to quantify patterns of bird distribution. Second, a description of the habitat types at sample plots where bird abundance was measured was needed to identify the plot-level habitat characteristics. Third, a map of land-cover types that would provide a description of the landscape patterns around the sample plots had to be created. Finally, I needed location coordinates for the sample plots so that the bird abundance data could be linked to the mapped data.

### Data Requirements

*Sampling Methods-Bird Abundance*

I used data on bird abundance that were collected over a three year period from an ongoing effort to quantify the biological diversity of the Boulder Open Space (Bock and Bock 1995). The study design included sixty-six 200-m diameter sample plots that were placed systematically within the Boulder Open Space properties to represent the natural variations present in the study area. Thirty-five plots were located in upland grassland habitat, and 31 in lowland tallgrass/hayfield habitat. The upland and lowland plots varied in terms of their proximity to urban development from sites as remote from urban development as is possible within the Boulder Open Space properties to locations immediately adjacent to an urban area.

Bird abundance was quantified on the plots using fixed distance (100 m) point counts (Reynolds et al. 1980). Ten counts were made of all birds over each of three nesting seasons (late May to Mid-July): 1994 (4 counts), 1995 (3 counts), 1996 (3 counts). Thirteen species were included in this analysis (Table 1), based on their preference for either urban or grassland nesting habitat (Bock et al., In press). Seventeen other passerine species were sighted over the three year period. None of these 17 species were grassland nesters nor did they exclusively nest in urban habitats. The species most commonly sighted that were not included in this analysis included Cliff Swallow (*Hirundo pyrrhonota*), Barn Swallow (*H. rustica*), and Black-billed Magpie (*Pica pica*).

*Determination of Habitat Types*

In order to determine the influence of habitat type on the bird community at the scale of the 200-m diameter plot, I used habitat categories derived by C. E. Bock from data collected by Bennett et al. (1997). The categories were based on vegetation species composition data collected during July 1995 and July 1996. Presence and absence data for all vascular plant species along a 50-m transect placed in a due west direction from the plot center were recorded. These plant abundance data were used to assign a habitat category of either mixed grass, shortgrass, tallgrass, or hayfield to each study plot. Three plots (3, 18, and 27), recently abandoned prairie dog towns, were dominated by exotic plant species. Rather than create a fifth habitat category for these three plots, I eliminated them from the analyses of habitat type effects.

*Location of sample plots*

Location coordinates for the sample plots were necessary to establish relationships between the bird abundance data and the landscape data. I collected Universal Transverse Mercator (UTM) coordinate data for all identifiable plot markers (n = 55) using Global Positioning Systems (GPS). The remainder of the plots (n = 11) were located in hayfields that were periodically mowed, making a permanent marker impractical. Coordinates for these plot locations were derived from a digital map provided by the City of Boulder Open Space Operations Center, which shows the plot locations as they were identified on orthophoto quad sheets by C. E. Bock.

*Land-cover mapping from Landsat data*

The first objective of the mapping effort was to represent the landscape patterns in the study area in a format compatible with automated GIS analysis techniques. Secondly, the mapped data needed to include a sufficient area surrounding the Open Space properties to allow description and analysis of landscape pattern at multiple scales, including areas up to one kilometer in all directions from the bird sample plots (Figure 1). I used Landsat Thematic Mapper (TM) imagery recorded August 31, 1995 to achieve these objectives. The Landsat image was georectified by I-CUBED using the State Plane coordinate system, (GRS 1980, Zone -501/3451, North American Datum 83) before being acquired by the City of Boulder Open Space Operations Center. Image classification was accomplished using ERDAS IMAGINE software version 8.2 on a Sun Sparc Workstation.

Landsat Thematic Mapper (TM) imagery is collected by a satellite-borne scanning optical-mechanical sensor system that records the reflected and emitted energy in seven regions of the electromagnetic spectrum (Table 2) (Jensen 1986). This sensor system can discriminate vegetation type and vigor, measure plant and soil moisture, and identify hydrothermal alteration in certain rock types (Jensen 1986). The instantaneous field of view (IFOV) is 28.5 x 28.5 m for bands 1-5 and 7, and 120 x 120 m for band 6. Data gathered from each imaging of the sensor consists of measurements of reflected and emitted energy in each of the seven bands. The data from each of the seven bands are stored in units called *pixels*, which represent one 28.5-by-28.5 meter portion of the earth's surface and are assembled into scenes covering approximately 100 by 115 miles of the Earth's surface.

If sufficient ancillary cover type data are available in digital form, these data can be used to train the computer to produce a supervised classification of the image. In a supervised approach, the computer uses the observed spectral characteristics of the locations with known cover types to determine spectral signatures for each cover type, and then assigns each pixel to the cover types whose spectral signature most closely matches the pixel's observed spectral characteristics. However, in this study, such ancillary data were unavailable, so an unsupervised classification method was used. ISODATA (Iterative-Self-Organizing-Data-Analysis-Technique) was used to identify spectrally similar clusters of pixels (ERDAS 1997). ISODATA determines the minimum spectral distance between arbitrary cluster means, and uses these distances to shift pixels among clusters. New cluster means can then be computed and the pixel shifting process can be repeated. Iterations continue until user-specified criteria regarding either the maximum number of iterations, or the maximum number of non-shifted pixels between two iterations have been met. The user must then assign a cover type to each of the clusters identified by the technique.

*Masking* was employed to reduce the spectral variability of the data, allowing easier identification of the cluster classes that are created by the unsupervised classification. In the masking approach, the pixels in the Landsat scene are divided into two or more groups (e.g. pixels representing urban areas and other pixels) and separate ISODATA analyses are performed on each group. This approach reduces the total variability present in each group, thereby producing more meaningful and easy to interpret results. In this study, a number of different masking schemes were tried. Three masks yielded the most readily interpretable results (Figure 2). The first mask included the foothills, the grasslands immediately north of the City of Boulder, and the southern grasslands extending toward the eastern edge of the map extent. The second included all urban and suburban areas and the agricultural areas in the north and northeastern parts of the study area. I used 25 cluster classes in each of these areas. The third mask, with 12 cluster classes, included the area directly east and southeast of the City of Boulder, where the majority of the remnant tallgrass prairie is located.

The cover types for each of the 62 clusters for all areas were then identified using mean signature plots (Appendix 1). The horizontal axis of these plots represents bands one through seven, and the vertical axis represents the average reflectance value for a cluster class. I interpreted the plots based on known characteristics of the TM sensor system (Table 2). For example, high reflectance in bands one and two indicate bare soil, rock or pavement, and a steeply sloping line between bands three and four indicates green vegetation. I grouped cluster classes that displayed similar patterns in their signature plots, and then assigned cover types to the grouped classes based on land-cover data gathered from bird sample plots located in the Boulder Open Space, and by using GIS vegetation coverages provided by the City and County of Boulder and the Arapaho-Roosevelt National Forest.

The resulting classification scheme (Table 3) represented a modified version of the Vertebrate Habitat Type classes defined by the City of Boulder Open Space. These classes could be identified with reasonable confidence. Scientists with the City and County of Boulder, and at the University of Colorado, provided input on the classification. Revisions were based on their input and extensive field checking during the summer and fall of 1996.

Map accuracy was estimated based on data collected using Global

Positioning Systems (GPS) at 86 randomly selected test points. I visited each of these 86 points and recorded a description of the actual land-cover present. I used the Kappa statistic (Czaplewski 1994) to compare the image classification with these ground truth data. Kappa values indicate a range from complete agreement between the two data sets (kappa = 1), to agreement expected by chance alone (kappa = 0). The kappa analysis measured overall map accuracy at 0.426, characterized in past studies as "fair" or "moderate" (Czaplewski 1994). Accuracies of individual classes varied from "excellent"/"almost perfect" (water, conifer), to "poor" (shortgrass, non-native hay/pasture) (Table 4a). Inaccuracies for grassland types were generally due to confusion between the types (see Error Matrix, Table 4a.).

The map's accuracy was also evaluated subjectively by C. E. Bock, who is extremely familiar with the study area. Because Dr. Bock expressed high confidence in the map's accuracy, I re-evaluated the methodology used to generate kappa statistics. Over 75% of the area on the land-cover map is within 30 m of the edge of another cover type. This characteristic probably accounted for the high degree of confusion represented by kappa for the individual cover types. I calculated the kappa statistics again using a subset of the ground truth data (n=43) that were recorded with a high level of confidence. All other points were recorded with lower confidence, because the field location was near to the edge of other cover types. This analysis resulted in higher values of kappa for overall and individual cover types (Table 4b.)

To gain further perspective on the issue of cover type accuracy, I performed a third analysis using combined cover types. The combined types were the most easily confused in the field, because of their spatial proximity to one another, and because they often occurred in small patches. For example, the two midgrass categories were highly interspersed in small patches. This analysis resulted in the highest overall accuracy, as well as the highest overall kappa (Table 4c.). Statistics for individual cover types indicate close agreement between the mapped cover type classes and the classes recorded at random points.

I ran a final test of kappa using the same combined cover types, except I also combined the non-native hay/pasture with midgrass types. Confusion in these categories probably resulted from the various mowing times and degree of wetness over the season. This analysis resulted in high kappa statistics for all cover types, and a high overall kappa (Figure 4d.).

*Sampling Methods-Landscape pattern*

Because I wanted to determine the effect of scale on identifying influences of landscape pattern, I measured pattern using various sizes of *geometric windows* (Dillworth et al. 1994). Windows are used to define sub-areas of interest from larger geographic regions. Geometric, or rectangular, windows of five sizes were centered on each sample plot location (Table 5). The smallest window size was chosen to represent an area slightly larger than the 200-m diameter sample plot. The largest window size (approximately 2,250 by 2,250 m) was chosen to represent an area that would likely be important to bird habitat selection, based on their extremely mobile nature.

New maps were created for each window (5 scales * 66 plots = 330 maps) using computer code written in C. Measures of landscape composition and configuration were calculated for each of these 330 maps. The particular landscape composition and structure indices used in this study are shown in Table 6. I chose these measures to explore their usefulness in describing the arrangement of cover-types in a grassland system, recognizing that they were developed to quantify patterns of forest fragmentation. Landscape metrics were calculated using FRAGSTATS (McGarigal and Marks 1995) and Arc/Grid (ESRI 1996). I used a summed value of urban vegetation and buildings/paved and a summed value of the two tallgrass categories for analyses. This simplified the description of relationships between bird abundance and urbanization, and the relationship between bird abundance and particular tallgrass types in the landscape.

## Statistics

I used Splus (StatSci 1997) and maps generated in Arc/Info (ESRI 1996) for preliminary analysis of the data. Mean abundance for each bird species was calculated by dividing the number of observations of each species by the total number of counts conducted in each plot. Moran's I (Cliff and Ord 1973) was used to test for spatial autocorrelation in residuals. Inverse distance (more weight was given to points closer together) was used to determine autocorrelation. I used the Spatial Library for Splus developed by R. Davis and R. Reich, professors at Colorado State University, to compute spatial statistics.

I examined the relationships between landscape measures and bird species abundance with regression techniques in order to see if relationships existed and to gain further insight on the best approach to describing patterns in the data. I applied linear regression models to the data using abundance of species groups (grassland nesters and suburban nesters, defined in Bock et al., In press) as dependent variables and landscape measures as independent variables. Comparison of Akaike's Information Criterion ($AIC_C$) for small sample size was used in model selection. Spatial autoregression models were used to describe the spatial autocorrelation present in the residuals of an ordinary least squares regression (Cressie 1991). This procedure involves selection of significant variables using ordinary least squares, testing for spatial correlation in the residuals with Moran's I, and then using spatial autoregressive techniques to derive additional terms that can be added to the original regression models to incorporate any spatial correlation.

To test the significance of landscape metrics to individual bird species, I used logistic, or binary regression models. Plots of species presence/absence data against landscape measures were used to screen for variables with potential significance. Model fit was determined by a $X^2$ test of residual deviance, where larger p-values indicated a better fit (Neter et al. 1996). Smaller $AIC_C$ indicated a better model choice.

I used an ordination technique, Canonical Correspondence Analysis (CCA) (Jongman et al. 1987), to describe the relationships between the bird abundance data and the habitat, landscape, and sample plot coordinate (locational) variables. I used a recently modified version of the CANOCO software (ter Braak 1987-1992) for ordination analyses. The modifications to CANOCO address criticisms of the stability of ordination results reported by Oksanen and Minchin (1997).

Conceptually, ordination assumes that sites (sample locations) and/or species can be arranged along environmental gradients. The theories and historical development of ordination can be found in Whittaker (1973) and Jongman et al. (1987). CCA is a weighted averaging ordination technique. The mathematical foundations of CCA have been described by ter Braak (1985, 1986, 1987). Palmer (1993) gave a simplified explanation of the method, which was used to present the following description of the CCA algorithm.

It is important to understand the precursor of CCA, which is Correspondence Analysis (CA). In the CA algorithm, four steps are performed in an iterative fashion. First, arbitrary numbers are assigned to each sample site (SITE SCORE). Second, the weighted average of the SITE SCORES at the sample sites where the species occurs is assigned to each species (SPECIES SCORE). Weights are the abundance of species in each sample site. The weighted average of the SITE SCORES is calculated as:

where the abundance of species $k$ at site $i$ is denoted by $y_{ki}$, the score of site $i$ is represented by $x_i$ and the score of species $k$ is denoted by $u_k$ (equations from

$$u_k=\sum_{i=1}^{n} y_{k\,i}\; x_i \;/\; \sum_{i=1}^{n} y_{k\,i}$$

Jongman et al. 1987). Third, the SPECIES SCORES are standardized (i.e. $\mu = 0$, $\delta^2 = 1$) to avoid scores tending toward zero. Fourth, new SITE SCORES are assigned as the weighted average of the SPECIES SCORES of all species that occur in the sample site. The weighted average of the SPECIES SCORES is calculated as:

$$x_i=\sum_{k=1}^{m} y_{k\,i}\; u_k \;/\; \sum_{k=1}^{m} y_{k\,i}$$

Reciprocal averaging and re-standardizing are repeated until there is no change (determined by comparison with a threshold value) in SPECIES SCORES and SITE SCORES between iterations. For an example of calculating SPECIES and SITE SCORES, see Jongman et al. (1987). The resulting scores constitute the first CA axis. Further axes can be calculated, with the constraint that each one is orthogonal to previous axes. The eigenvalue is a measure of importance of the ordination axis, ranging from 0 (no correlation) to 1 (high correlation).

Additional steps that take advantage of available environmental data are included in the CA algorithm during CCA. After step four (described above), a multiple linear least-squares regression is performed with the SITE SCORES (determined from weighted average of the SPECIES SCORES) as the dependent variables, and the environmental variables as the independent variables. Then, the values predicted using the regression equation are assigned as the NEW SITE

SCORES. These NEW SITE SCORES are linear combinations of the environmental variables. The NEW SITE SCORES are then used in subsequent iterations of the algorithm.

The NEW SITE SCORES produced by CCA are used to plot an *ordination diagram* that allows visualization of the species/environment relationships (Figure 3). Environmental variables are represented by lines of lengths proportional to their importance, and direction indicative of correlations between variables. The position of a species along a gradient is determined by drawing a perpendicular line from the species point to the gradient line (Figure 3.) To evaluate an axis quantitatively, its eigenvalue is used. The eigenvalue measures how much variation in the species data is explained by the axis, and therefore, by the environmental variables. I used the eigenvalues from analyses using various combinations of the data sets to compare models that explain the variation in the species abundance data.

I used methods proposed by Borcard et al. (1992) to partition the habitat, landscape, and spatial components of the variation in the species data. I compared different models in CCA using the habitat, landscape, and location coordinate variables (Table 7). The resulting sum of all canonical eigenvalues was used to calculate the proportion of variability explained relative to the total variation in the bird species matrix.

To describe spatial structure in the data, I derived a location coordinate matrix using steps described by Legendre (1990). This matrix, *Z*, included the geographical coordinates, $x$ and $y$, and all terms for a cubic trend surface regression. The initial matrix contained:

$$x \quad y \quad x^2 \quad xy \quad y^2 \quad x^3 \quad x^2y \quad xy^2 \quad y^3$$

for all 66 sample plots. I used the forward selection procedure in CANOCO to select model terms related to the bird abundance matrix, and five terms remained in the matrix:

$$Z = b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2$$

In the CANOCO software, effects of a set of variables (e.g., landscape) are isolated by first determining the collinearity between those variables and another set (e.g., habitat type). Collinearity between location variables and other variables is of interest because it reflects a common spatial structuring that can be used to infer common underlying causal processes (Borchard and Legendre 1994).

Initially, I tested the significance of the landscape variables at three scales (I, III, V) to evaluate the usefulness of the composition and configuration variables for describing bird community structure, using unrestricted Monte Carlo permutation tests (ter Braak 1987-1992) (Table 8). I compared models that included the landscape composition variables at all five scales in order to determine which explained the greatest proportion of variation in the species data. Landscape data at the "best" scale were used in all subsequent models. Then, I tested each model in CCA (Table 7) to describe the proportion of the variation in the bird species matrix explained by each set of variables.

## Chapter III

## Results

*Landscape Pattern Description*

The landscape context of the sample plots was dominated by the extensive background matrix of native and introduced grasslands (Figure 4). The midgrass, tallgrass, and hay/pasture cover types dominated all other cover types at all five scales (Figure 5). The scale of the analysis profoundly influenced the description of landscape. The mean percent of each analysis window classified as urban gradually increased as window size increased (Figure 6). The distribution of urban cover types at scale V was similar to scale IV, but the mean percentage at scale V was higher than that at scale IV due to several outliers in the scale V data. Urban composition did not influence landscape analyses at scale I because of its limited distribution. In general, the mean percent of grassland cover types decreased as mean percent of urban cover types increased in the landscape.

The change in variance, or distribution of variables, between scales reflected the shift in dominance away from grassland types toward urban types in the landscape. The largest change in variance between scales occurred between scales I and II for the following variables: percent urban, perimeter/area ratio, percent tallgrass, contagion, and dlfd (double log fractal dimension) (Figure 7). The largest change in variance for number of patches, however, occurred at scale V.

*Habitat Preference*

Some bird species showed a preference for certain habitat types at the scale of the sample plot. Based on number of occurrences in each habitat type, the Savannah Sparrow and the Bobolink preferred tallgrass and hayfield habitats (Table 9). The Horned Lark and the Lark Sparrow were only observed in upland habitats (shortgrass or mixed grass). Red-winged Blackbird, Robin, and Common Grackle were more common in lowland plots. The Grasshopper Sparrow and Vesper Sparrow were more often sighted in upland plots. Species with no apparent preference based on the raw count data included Western Meadowlark, European Starling, House Finch, and House Sparrow.

In a few cases, species that preferred the same habitat type exhibited differences in spatial distribution among the plots (Figure 8). Horned Lark and Lark Sparrow occurred in similar upland habitats, but never occurred together at the same plot. Furthermore, a majority of plots where the Horned Lark occurred were in the expansive mixed and shortgrass areas in the south, whereas the Lark Sparrow was only observed in the block of mixed and shortgrass north of the city of Boulder. The distribution of Savannah Sparrows and Bobolinks overlapped at tallgrass and hayfield plots.

*Importance of Landscape Context*

Grassland-nesting bird species generally preferred areas with a less urbanized landscape. Scatter plots of bird abundance for individual grassland species and urban context (percent of combined urban cover types) at scales II through V exhibited similar patterns, with a large amount of variation in abundance at low levels of urban context (Figure 9.). High levels of bird abundance rarely occurred at higher levels of urban landscape composition. Pearson's correlation coefficient indicated significant negative correlations ($p < 0.05$) between Meadowlark, Grasshopper Sparrow, and Vesper Sparrow abundance and urban context at scale III. Among the individual species analyzed using logistic regression, only the Grasshopper Sparrow showed a significant negative relationship with urban landscape context (Table 10).

The negative relationship between grassland bird abundance and urbanization was influenced by spatial structure. Ordinary least squares regression analysis showed significant negative relationships between grassland bird abundance, when abundance values for the eight species were combined, and percent urban composition at scales II, III, IV, and V. AICC statistics varied from 276.636 (scale II) to 267.0711 (scale V). The differences in AICC values were not great enough to select a "best" model. The residuals from the scale V regression contained spatial autocorrelation (Moran's I = 0.175, $p < 0.001$). The coefficient from spatial autoregression was correspondingly high (lambda = 0.7983).

Suburban-nesting bird species were more common on sample plots within a more urbanized landscape. The European Starling and House Sparrow had significant positive relationships with urban composition at scales II, III, IV and IV (Pearson's correlation coefficient $p < 0.05$). Results of regression analysis confirmed correlation of suburban nesters with urban composition at scales II, III, IV, and V. The "best" model included urban data at scale III (AICC = 281.3844). AICC values did not differ greatly, but I used the data at scale III to evaluate the spatial autocorrelation, which was significant (Moran's I = 0.144, $p < 0.001$). The significance of the spatial effects were reflected in the high value of lambda (0.7152). Using logistic regression, a significant positive relationship was identified between the House Sparrow and urban context.

Grassland bird species associated with certain habitat types at the plot level were more abundant in landscapes with higher percent composition of their preferred grassland types. Maximum levels of abundance for the Lark Sparrow and Horned Lark were only observed at the highest levels of upland grassland type composition (sum of midgrass/mixed grass and midgrass/shortgrass) (Figure 10). Scatterplots of Savannah Sparrow and Bobolink abundance against lowland grassland landscape composition measures (sum of tallgrass and hay/pasture types) exhibited similar patterns. There was a significant positive relationship between these species' abundance and grassland composition variables at scale III in tests of Pearson's Correlation Coefficient ($p < 0.05$).

*Bird Community Patterns in Relation to Landscape Structure*

Avian community structure was strongly influenced by landscape context. The ordination diagrams confirmed the importance of landscape context to grassland and suburban species at the three scales analyzed in CCA (Figure 11a. - 11c.). Species associated with landscapes dominated by upland grasses and those species associated with lowland tallgrass or hayfield landscapes were grouped along these gradients. Quadrant locations of particular grassland species reflected their affinity for landscape context of a particular grassland type. For example, the Bobolink, Savannah Sparrow, and Red-winged Blackbird were all located at the high end of the tallgrass and wetland gradients in the ordination diagrams. The first axis (horizontal) was highly correlated with percent mixed grass and percent shortgrass cover types at all three scales and the eigenvalue of this axis indicated a strong gradient (Figure 11a. - 11c.).

The percent of urban cover types in the landscape was not as important as the percent of grassland types in determining bird community structure. The second axis (vertical) was correlated with percent urban cover types at scales III and V, but this axis had a low eigenvalue (< 0.3), indicating a weak gradient (ter Braak and Verdonschot 1995). At scales III and V, the suburban species were grouped at the high end of the urban gradient, and the grassland species fell at the lower end of this gradient. The Bobolink was an exception, and fell at the midpoint of the urban gradient.

The variation in the species community data explained by the landscape data increased with scale (Figures 11a. - 11c.). At scale I, 34.99% of the variation was accounted for by the set of independent variables. Two of the landscape configuration indices were significant to the ordination at this scale (Table 8). Fractal dimension and perimeter/area ratio were non-sigificant for scales I, III, and V. At scale III, more of the predictive power was contained in the independent variables (39.73% explained variation). One of the landscape indices (contagion) was significant at this scale, and the composition variables differed somewhat from those included at scale I. At scale V, 45.90% of the variation was explained by the landscape variables (n = 66). Six of the composition variables were significant to the ordination at scale V, but none of the configuration indices were significant. Because the variables at scale V explained the greatest amount of variation, these variables were used in further analysis of landscape influence on the bird species.

*Bird Community Patterns in Relation to Habitat Type*

Habitat type played a role in determining bird community structure. However, landscape context had an even greater influence on avian patterns. Analysis of habitat effects using CCA explained roughly 26.43% of the variation in the bird data (Table 11). I compared this analysis with the results using landscape data (cover type composition only) from scale V. The landscape data explained a higher percentage of the variation than the habitat type data (46.20%). There was a substantial amount of collinearity in the landscape and habitat data, however, as 17.70% of the variability explained by landscape could also be explained by habitat type (Table 12).

*The Importance of Location*

The structure of the avian community was influenced by geographic location. A common spatial structuring existed between the landscape and habitat variables, indicated by a fair amount of collinearity between the landscape and habitat variables and the geographic coordinate matrix (Table 12). Some variation in the bird species data was explained by the location matrix (12.98%), but could not be related to the landscape/habitat variables. A substantial amount of variation was unexplained after habitat, landscape, and location were taken into account. This indicated that other, unmeasured factors, were influencing the bird community structure.

# Chapter IV

## Discussion

### *Interrelationships: Landscape Scale and Bird Community Patterns*

Influences on the bird species community in the Boulder Open Space were apparent at different spatial scales. At the scale of the sample plot, habitat preferences played a role in determining bird community structure. However, these patterns were not as clear and definitive as the patterns of distribution related to landscape context. The extensive grassland mosaic captured in measurements at the 6-ha scale were interrupted by patterns of urban encroachment at the 40-ha scale.

The area between 6 and 40 ha is the geographic scale at which processes and patterns associated with urbanization were evident, both in terms of bird community and landscape characteristics. Landscape patterns at this scale reflect two components of change; an increase in area of urban cover types and a decrease in area of grassland cover types. Detectible change in landscape pattern at these scales may be related to the location of the bird sample plots, many of which were positioned at the edge of a suburban development.

The scale-dependent patterns were most closely related to the area of grassland cover types. The results of the ordination analyses indicate that the patterns of grassland habitat in the landscape were more important than the amount of urban habitat in structuring the bird community. Urban landscape composition was a significant variable in the ordination analysis. However, a weak gradient was indicated by the axis associated with this variable. Composition of grassland types, especially midgrass and shortgrass types, had a stronger role in determining bird community patterns. A common characteristic of fragmentation is the loss of area in certain habitat types, and its subsequent replacement by some other type, or land use (Andren 1994). This change in habitat composition occurred in the Boulder study area, where the mean of the grassland habitat types decreased as the mean of the urban cover types increased in the landscape. Based on the results of my study, I hypothesize that the more important component of change is the decrease in grassland cover types, rather than the increase in urban types. It may be possible to test this hypothesis if study areas could be identified where grassland habitats were being replaced by non-urban cover types.

The relationship between urban landscape context and individual grassland bird species abundance suggested by the scatterplots (Figure 9) was not confirmed by the ordination results, perhaps because there were fewer suburban nesters included in the analysis. Ordination provided a description of the bird community in relation to landscape gradients using species abundances at the sample sites where they were observed to weight the ordination. The relatively greater importance of the grassland gradients compared to the urban gradient may have resulted from inclusion of fewer suburban nesting species.

The importance of landscape context in explaining bird community structure was also noted in other studies. Pearson (1993) reported similar results in his study of wintering birds in the Georgia piedmont, where 30-90 % of the variation in bird abundance and diversity was accounted for by landscape variables. Knight and Morris (1996) emphasize the importance of examining the effects of habitat selection before assessing the role of landscape composition and structure. In my study, as well as Pearson's (1993), habitat type was also an important component of the variation. The results of this study indicate that much of the effect of habitat type can be also be predicted by landscape context.

*The Importance of Location*

Geographic location explained some of the variation in bird distribution and abundance. Locational analysis identified a common spatial structure between bird community and landscape patterns. Spatial structure reflects the non-uniform and non-random manner in which biological and environmental components of nature are distributed (Legendre 1993). The action of physical processes structuring the arrangement of these components is visible in either gradients or patchiness on the landscape.

The effects of geomorphology, hydrology, and land use on landscape patterns are visible in the land-cover maps (Figures 4 and 12). A geomorphological shift occurs at the mountain-plains boundary. To the east of this boundary, the extensive background grassland matrix is patterned by the hydrology of Boulder Creek, and land use practices driven by economy, politics and culture. The factors determining land use are intertwined, but the results of these forces are evident in grazing regimes (reflected in patterns of midgrass and shortgrass cover types), extent of agricultural areas, and the preservation of grassland habitats in Open Space properties (delineated in Figure 1).

Additional spatial structuring in communities may result from biotic interactions such as predation, competition, reproduction, and death. Spatial structuring in the Boulder bird community may be linked to biotic interactions resulting from urban/grassland landscape patterns. The mosaic of cover types in the urbanized landscape may provide opportunities for invasion by species not adapted to grasslands, such as the urban nesters observed in this study. Uninterrupted expanses of grassland habitat contain few patches of different cover types that may serve as *refugia* for species not adapted to the variations in climate and resources present in grassland habitats (Wiens 1974). Patches of urban vegetation may allow non-grassland species, such as European Starlings, American Robins, House Sparrows, House Finches and Common Grackles, to exploit grassland resources when climate and productivity are favorable. Increased opportunities for utilization of grassland resources by non-grassland species may lead to interspecific competition for resources.

*Biogeography and Urbanization*

Biogeographical boundaries reflecting changes in bird abundance patterns in the Great Plains are likely related to climate (Bock et al. 1977). A predominant gradient in moisture regimes probably influences bird abundance patterns indirectly through its effects on vegetation patterns. Urbanization can override the effects of climate, moderating the extremes of climate at local scales, and is a powerful disturbance in itself (Jokimaki and Suhonen 1993). Studies in Finland demonstrate the effects of urbanization on species composition and diversity. Based on their biogeographical analysis, the effects of latitude are apparently tempered by the urban environment. An interesting question for future study would be: How are micro- and macro-climatic effects of urbanization changing the distribution of species in Front Range grassland communities?

The need to integrate ecological and biogeographical principles has been emphasized (Bock 1987). At a regional scale, the dimension of geographic variation in abundance adds *important information* to maps of species distribution. The observed local distributions in the Lark Sparrow and the Horned Lark demonstrate such geographic variation. The geographic range of these species coincides regionally, but effects of either abiotic (e.g., climate) or biotic (e.g., interspecific competition) variables at the local scale prevail over broader-scale influences (Wiens 1989b). It was hypothesized that local habitat features, such as shale soils, influenced the Lark Sparrow's distribution (C.E. Bock, pers. comm.). This soil type occurs mainly in the areas where Lark Sparrows were observed. An alternate hypothesis was that the presence of one species precludes that of the other, because of biotic interactions (e.g., competition). The Savannah Sparrow and Bobolink occurred only in tallgrass or hayfield plots, but their distribution among these plots overlapped. Habitat type descriptions at finer scales may be needed to interpret overlapping distributions.

*Common vs. Rare Species*

The results of this study relate to the importance of comparing common and rare species discussed by Bock (1987). Wide geographic distribution and high abundance are often correlated, implying that common species share ecological characteristics that differ from those of rare species. In my study, I compared a group of "common" species (suburban nesters) with "rare" species (grassland nesters). The differing ecological properties of common and rare species emerged along the gradients of landscape pattern. What processes are involved in creating the observed patterns among common and rare species in my study? Does predation of ground-nesting grassland birds by domestic animals influence their distribution in urbanized landscapes? Do these two groups of species respond differently to environmental effects of urbanization, such as noise levels and levels of human activity?

*Other Considerations*

*Data Sources and Classification Scheme*

Description of landscape pattern at any scale is directly related to the data source used to create the map. The resolution of the data source in this study was determined by the spatial extent of the area to be mapped, and the classification scheme was chosen to relate to boundaries considered important to species of interest. In using mapped data, it is important to recognize maps as models; an alternative form of looking at reality that incorporates cartographical conventions of generalization, feature displacement and symbolization (Laurini and Thompson 1992). The result of modeling the landscape in this fashion is likely to have a strong element of human perception.

The classification scheme I used was fairly detailed. Successful descriptions of habitat relationships depend on identification of habitat types that species of interest recognize (Knight and Morris 1996). In Knight and Morris' study of small mammal species, the large number of habitat classes identified with satellite imagery were excessive in describing the three types of habitat found to be important to habitat selection. It is possible that this may be the case in my analysis, and a simplified classification of landscape cover types could provide adequate, or better, results. It is also worth considering that more detailed categories of plot-level habitat types would provide a fairer analysis for comparison of the importance of habitat versus landscape components of variation. In my study, the importance of landscape may have been more evident because I used more detail in landscape description, including five scales of analysis. The distribution of the Horned Lark and Lark Sparrow indicated the possible importance of finer scale habitat information (e.g., soil type). The addition of detail in the habitat categories could increase the detection of their role in determining bird distribution and abundance.

### *Description of Landscape Pattern*

There is a spectrum of spatial pattern created by disturbance. Fragmentation has been emphasized (e.g. Herkert 1994), but other descriptions may be better suited to grasslands in general, and to the Boulder landscape in particular. Identification of useful landscape metrics needs further research. Patterns created by urbanization might be best described by metrics that capture "shrinkage" or "attrition" (Forman 1995), or "indentation" (Zipperer 1993). A limitation of fragmentation metrics may be their development in computer simulations that have no link to ecological phenomena (e.g. O'Neill et al. 1988, Turner et al. 1989). A metric that best describes patterns of importance reasonably needs to be derived for a specific research question and a particular study area. This was the approach taken by Shumaker (1996), who developed a pattern index that was consistent with predictions for dispersal success.

*Scale*

Considering scale as a primary focus of research efforts has been advocated by Wiens (1989b). Observations from this study provide insights toward that direction. A common issue in research whose purpose is to relate biological processes (e.g. distribution, abundance, reproductive success, dispersion) to landscape patterns at multiple scales is the spatial arrangement of sample sites. Using GIS, sampling of landscape pattern is only limited by the map extent, but observations of biological processes are restricted by a number of factors. In some cases, sampling is determined by the location of nest sites (e.g. Baker et al. 1995). A very common situation is the need to sample within political boundaries, especially on publicly owned lands.

The location of the bird sample plots for the Boulder study affected the landscape pattern description, and the ability to detect heterogeneity at multiple scales. The averaging of effects of local heterogeneity at broader scales (Wiens 1989b) is altered when sample sites are close together relative to scales of interest. As the size of the window increases, more and more overlap occurs between windows, and spatial correlation becomes spatial identity where sample plots occur in clusters. In essence, 66 landscapes are reduced to a smaller number of grouped landscapes (Figure 13).

This overlap in landscape pattern data could be the cause of the increased amount of variability explained at larger area scales using CCA. Rather than a simple averaging effect, increased explanatory power may have resulted because more samples had similar values. In terms of identification of changes in heterogeneity, however, no scale thresholds were identified beyond the two smallest areas. The windows at these scales had the least amount of overlap.

*Conclusion*

Some implications for bird conservation in grasslands near Boulder, Colorado, and for future investigations of bird distribution and abundance in relation to habitat and landscape characteristics can be made based on observed patterns. The significance of grassland cover type composition in the landscape in relation to bird abundance and distribution would indicate the need to conserve large areas of grassland habitat. However, observed patterns in bird abundance in relation to urban landscape context indicate grassland birds occur more abundantly at low levels of an urban gradient. In addition, two hypothesis related to biotic factors are linked to the assumption that urban cover types are a critical component of community structuring. First, the idea that competition with suburban nesting species may influence the distribution of grassland nesting species leaves open the possibility that urban cover types provide opportunities for this interspecific competition that would not otherwise exist. Second, the hypothesis that predation by domestic animals affects bird abundance and distribution in grasslands is predicated on the interspersion of urban and grassland cover types.

Further investigations are needed to confirm and clarify these observations. The unequal number of grassland bird species compared to suburban nesting birds may have led to under-emphasis of the importance of urban cover types in determining distribution of bird species in Boulder area grasslands. A study designed to isolate the effects of grassland habitat loss would provide insight into the relative importance of shifts in grassland/urban area. Furthermore, additional detail in plot-level habitat type descriptions could provide a fairer comparison between landscape and habitat effects in structuring the bird community.

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Table 1. Grassland and suburban nesting bird species observed in the Boulder Open Space sample plots.

| Common name | Scientific name | Grassland (G)/ Suburban (S) |
|---|---|---|
| Savannah sparrow | *Passerculus sandwichensis* | G |
| Western meadowlark | *Sturnella neglecta* | G |
| Bobolink | *Dolichonyx oryzivorus* | G |
| Grasshopper sparrow | *Ammodramus savannarum* | G |
| Horned lark | *Eremophila alpestris* | G |
| Vesper sparrow | *Pooecetes gramineus* | G |
| Lark sparrow | *Chondestes grammacus* | G |
| Red-winged blackbird | *Agelaius phoeniceus* | G |
| American Robin | *Turdus migratorius* | S |
| European starling | *Sturnus vulgaris* | S |
| Common grackle | *Quiscalus quiscula* | S |
| House finch | *Carpodacus mexicanus* | S |
| House sparrow | *Passer domesticus* | S |

Table 2. Earth surface characteristics detected by the Thematic Mapper Spectral Bands.

| Region of the Electromagnetic Spectrum (measured in micrometers) | Reflectance Properties |
|---|---|
| Band 1: 0.45-0.52 | Penetration of water bodies |
| Band 2: 0.52-0.60 | Green reflectance of healthy vegetation |
| Band 3: 0.63-0.69 | Red chlorophyll absorption, vegetation |
| Band 4: 0.76-0.90 | Vegetation biomass |
| Band 5: 1.55-1.75 | Turgidity of plants; clouds, snow, ice |
| Band 6: 10.4-12.5 | Temperature |
| Band 7: 2.08-2.35 | Geologic formations |

Table 3. Classification scheme for the land-cover map of the study area. Categories and cover-type names were modified from the City of Boulder Open Space Vertebrate Habitat Classification System.

| Category | Cover-Type Name |
|---|---|
| Water/wetlands | Water |
| | Wetland/Riparian |
| Forest/shrublands | Conifer forest |
| | Ponderosa pine/shrub savannah |
| | Ponderosa pine forest/woodland |
| | Shrubs |
| Grassland types | Midgrass/shortgrass |
| | Midgrass/mixed grass |
| | Non-native hay/pasture |
| | Native tallgrass (wetter) |
| | Native tallgrass (drier) |
| Other | Bare rock/soil |
| | Buildings/paved |
| | Urban vegetation |

Table 4a. Error matrix and kappa statistics used for map accuracy assessment. Row and column numbers correspond to cover types listed, below. Rows are data from random points (n=86), columns are data from the land cover map. No individual accuracy assessment was possible for 5.wetland/riparian (no samples).

Error Matrix

| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 3 | 4 | 5 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6 | 0 | 1 | 0 | 2 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 3 | 3 | 8 | 0 | 3 | 0 | 0 | 0 | 2 |
| 8 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 4 | 1 | 0 | 0 |
| 12 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 11 | 0 | 0 |
| 13 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

Kappa Statistics

Overall accuracy 0.5
Overall Kappa 0.426

Table 4a. Continued.

| Cover type number and name | Individual Kappa Statistics |
|---|---|
| 1. Water | 1.00000000 |
| 2. Conifer | 1.00000000 |
| 3. Ponderosa pine/shrub savannah | 0.58554217 |
| 4. Midgrass/mixed grass | 0.11794872 |
| 5. Wetland/riparian | no samples |
| 6. Midgrass/shortgrass | 0.23555556 |
| 7. Non-native hay/pasture | 0.24561404 |
| 8. Ponderosa pine forest/woodland | 0.24117647 |
| 9. Shrubs | 0.80888889 |
| 10. Bare rock/soil | 0.54497354 |
| 11. Buildings/paved | 0.63682432 |
| 12. Urban vegetation | 0.48809524 |
| 13. Native tallgrass (wetter) | -0.02380952 |
| 14. Native tallgrass | 0.00000000 |

Table 4b. Error matrix and kappa statistics using "high confidence" random points (see text).. Row and column numbers correspond to cover types listed, below. Rows are data from random points (n=43), columns are data from the land cover map.

Error Matrix

| | 4 | 6 | 7 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6 | 1 | 3 | 0 | 1 | 1 | 0 | 0 | 0 |
| 7 | 2 | 3 | 7 | 2 | 0 | 0 | 1 | 1 |
| 10 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 12 | 0 | 0 | 1 | 0 | 2 | 6 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 14 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

Overall accuracy 0.5581
Overall Kappa 0.4702

| Cover type number and name | Individual Kappa Statistics |
|---|---|
| 4. Midgrass/mixed grass | 0.43421053 |
| 6. Midgrass/shortgrass | 0.41891892 |
| 7. Non-native hay/pasture | 0.28860294 |
| 10. Bare rock/soil | 0.75428571 |
| 11. Buildings/paved | 1.00000000 |
| 12. Urban vegetation | 0.60185185 |
| 13. Native tallgrass (wetter) | 1.00000000 |
| 14. Native tallgrass | -0.02380952 |

Table 4c. Kappa statistics using combined cover types (midgrass types, tallgrass types, urban types and conifer types).

Error Matrix

| | 1 | 2 | 6 | 7 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 8 | 2 | 0 | 0 | 0 | 0 |
| 6 | 0 | 1 | 12 | 7 | 2 | 0 | 0 |
| 7 | 0 | 0 | 6 | 8 | 3 | 0 | 2 |
| 10 | 0 | 0 | 0 | 1 | 5 | 0 | 0 |
| 12 | 0 | 0 | 1 | 4 | 1 | 17 | 0 |
| 14 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |

Overall accuracy 0.6395
Overall Kappa 0.553

| Cover type name and number | Individual Kappa Statistics |
|---|---|
| 1. Water | 1.0000000 |
| 2. Conifer types | 0.7766234 |
| 6. Midgrass types | 0.3892045 |
| 7. Non-native hay/pasture | 0.2456140 |
| 10. Bare rock/soil | 0.8088889 |
| 12. Urban types | 0.6748582 |
| 14. Tallgrass types | 0.6504065 |

Table 4d. Kappa statistics using combined cover types (midgrass and hayfield types, tallgrass types, urban types and conifer types).

Error Matrix

| | 1 | 2 | 6 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 8 | 2 | 0 | 0 | 0 |
| 6 | 0 | 1 | 33 | 5 | 0 | 2 |
| 10 | 0 | 0 | 1 | 5 | 0 | 0 |
| 12 | 0 | 0 | 5 | 1 | 17 | 0 |
| 14 | 0 | 0 | 1 | 0 | 0 | 2 |

Overall accuracy 0.7907
Overall Kappa 0.6968

| Cover type name and number | Individual Kappa Statistics |
|---|---|
| 1. Water | 1.0000000 |
| 2. Conifer types | 0.7766234 |
| 6. Midgrass and Hayfield types | 0.6186253 |
| 10. Bare rock/soil | 0.8088889 |
| 12. Urban types | 0.6748582 |
| 14. Tallgrass types | 0.6504065 |

Table 5. Window sizes defining scales at which landscape pattern was measured around bird sample plots.

| Scale | Number of pixels | Approximate area (ha) |
|---|---|---|
| I | 9 by 9 | 6 |
| II | 23 by 23 | 40 |
| III | 37 by 37 | 103 |
| IV | 57 by 57 | 244 |
| V | 75 by 75 | 423 |

Table 6. Indices of landscape pattern calculated for each window size, for all 66 plots.

| Category | Index | Definition | Interpretation |
|---|---|---|---|
| Composition | | | |
| Patch Type Diversity | Area of each covertype | percent area of each covertype | Covertype composition |
| Configuration | | | |
| Number of Patches | Total number of patches in the landscape | Count of all patches | Fragmentation |
| Association/Dispersion of patches | Relative Contagion (RC) | Given two randomly chosen cells, cell(i) and cell(j): P(cell(i) adjacent to cell(j)) | Extent of aggregation or clumping. |
| Patch complexity | Fractal Dimension (dlfd) | dlfd = 2 * slope of the regression line of log(area) against log(perimeter) | Edge complexity. dlfd = 1, simple shape dlfd = 2, complex shape |
| | Perimeter/area ratio | Total perimeter/total area | Relative edge complexity |

Table 7. Models tested in CCA. Both combinations of variables were tested in models 3 and 6. For example, in model 3, first test the significance of habitat after removing the effects of the landscape variables. Second test the significance of landscape after removing the effects of the habitat type variables.

| Model Components |
|---|
| 1) Landscape composition (scales I - V) |
| 2) Habitat type |
| 3) Landscape composition V + Habitat type |
| 4) Habitat type/Landscape composition V (combined matrix) |
| 5) Location |
| 6) Habitat type/Landscape composition V + Location |

Table 8. Landscape variables used in CCA. Variables with significant p-values ($p < 0.05$) are indicated for each scale. Significance was determined using forward selection with Monte Carlo permutation tests ($n = 9999$) in CANOCO.

| Landscape variable | Significance | | |
|---|---|---|---|
| | Scale | | |
| | I | III | V |
| Midgrass / mixed grass | * | * | * |
| Midgrass / shortgrass | * | * | * |
| Wetland / riparian | | | * |
| Non-native hay / pasture | * | | * |
| Native tallgrass | * | * | * |
| Urban vegetation, buildings and pavement | | * | * |
| Number of patches | * | | |
| Contagion | * | * | |

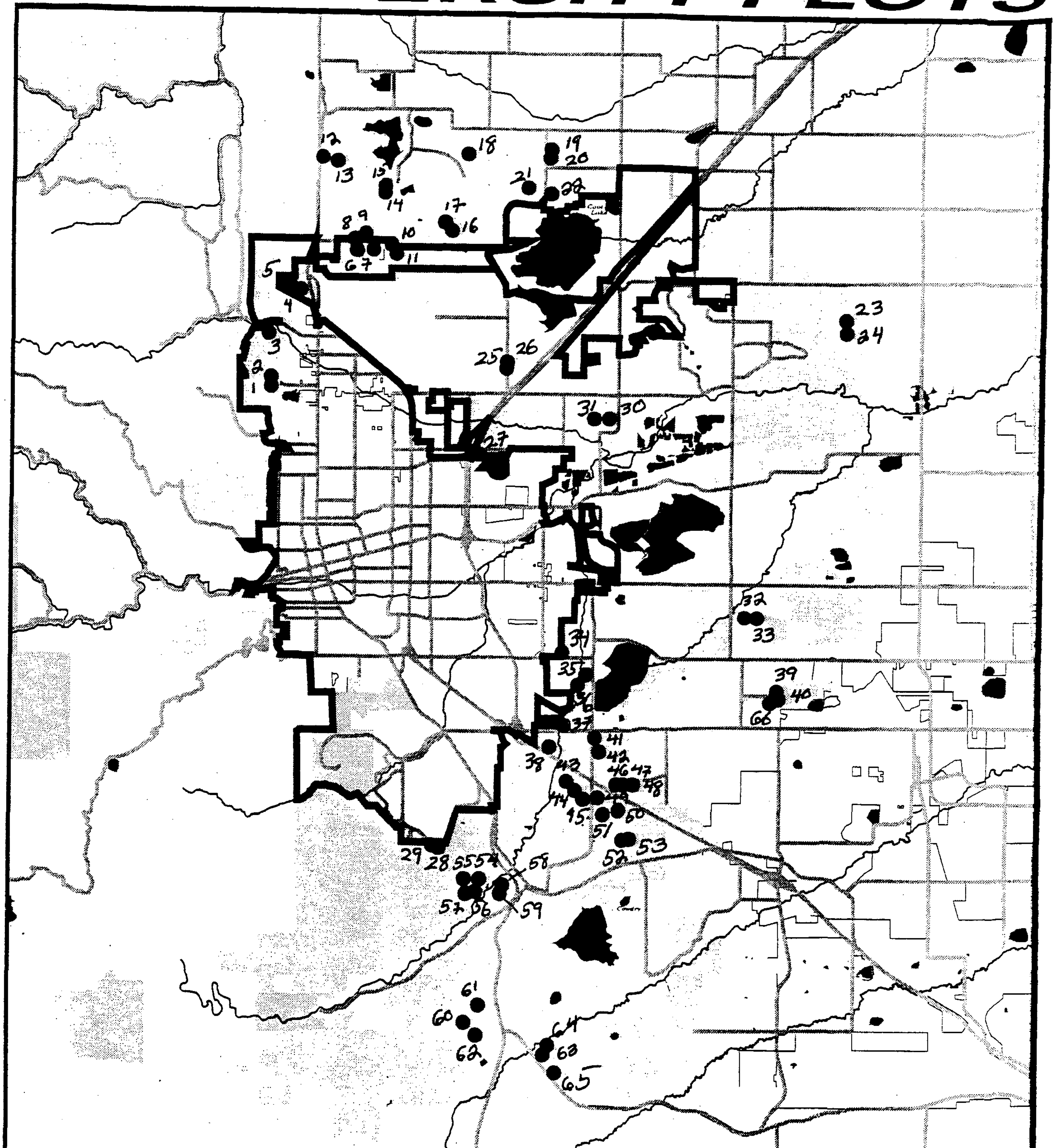
Table 9. Number of occurrences of each bird species at plots described by habitat category. Percent of total occurrences for each habitat type is reported in parentheses.

| Bird Species | Tallgrass | Hayfield | Shortgrass | Mixed grass | Total occurrences |
|---|---|---|---|---|---|
| Savannah sparrow | 4 (33) | 8 (66) | 0 | 0 | 12 |
| Western meadowlark | 11 (17) | 20 (32) | 16 (25) | 16 (25) | 63 |
| Bobolink | 6 (33) | 12 (66) | 0 | 0 | 18 |
| Grasshopper sparrow | 7 (24) | 2 (7) | 6 (21) | 14 (48) | 29 |
| Horned lark | 0 | 0 | 8 (66) | 4 (33) | 12 |
| Vesper sparrow | 5 (14) | 7 (19) | 12 (33) | 12 (33) | 36 |
| Lark sparrow | 0 | 0 | 8 (62) | 5 (38) | 13 |
| Red-winged blackbird | 9 (31) | 17 (59) | 2 (7) | 1 (3) | 29 |
| Robin | 9 (29) | 14 (45) | 4 (13) | 4 (13) | 31 |
| European starling | 10 (20) | 20 (40) | 12 (24) | 8 (16) | 50 |
| Common grackle | 10 (24) | 20 (48) | 7 (17) | 5 (12) | 42 |
| House finch | 8 (24) | 11 (33) | 8 (24) | 6 (18) | 33 |
| House sparrow | 1 (10) | 5 (50) | 1 (10) | 3 (30) | 10 |

Table 10. Results of logistic regression analysis for single species. Larger p-values indicate better model fit. Smaller AICC values indicate a better model choice. Models included presence/absence for individual species as the dependent variable, and landscape variables as *independent* variables.

| Species | Variable tested (scale) | p-value | t | AICC |
|---|---|---|---|---|
| Horned lark | number of patches (I) | 0.76 | -2.27 | 56.0 |
| | midgrass/mixed grass (III) | 0.76 | 2.11 | 55.7 |
| | urban (V) | | $< \lvert 2 \rvert$ | |
| House sparrow | urban (III) | 0.92 | 3.43 | 49.3 |
| | midgrass/shortgrass (III) | | $< \lvert 2 \rvert$ | |
| Bobolink | tallgrass (I) | 0.95 | 4.6 | 47.0 |
| | urban (III) | | $< \lvert 2 \rvert$ | |
| Lark sparrow | midgrass/shortgrass (I) | 0.51 | 2.65 | 63.3 |
| | midgrass/shortgrass (III) | 0.97 | 4.03 | 44.4 |
| | urban (III, V) | | $< \lvert 2 \rvert$ | |

# CITY OF BOULDER OPEN SPACE
# BIO-DIVERSITY PLOTS




City Open Space
County Open Space
Mountain Parks
Bio-diversity Plots
City Limits
Creeks
Fed/State Lands

N
W
E
S

Scale in Miles
0 1/2 1

*Map produced from the City of Boulder's Open Space/Real Estate Geographic Information System. Computer Cartography - J. Holland - The GIS Lab. Jan. 21, 1994*

*Original fieldwork completed on PSCO 1:400 1984 orthographic aerial photography digitized and assembled in AutoCAD. Map created from .DXF output in Corel Draw*

*For further information, revisions or comments please contact the City of Boulder Open Space GIS Lab at 66 S. Cherryvale Road, Boulder CO 80303 (441-4495)*

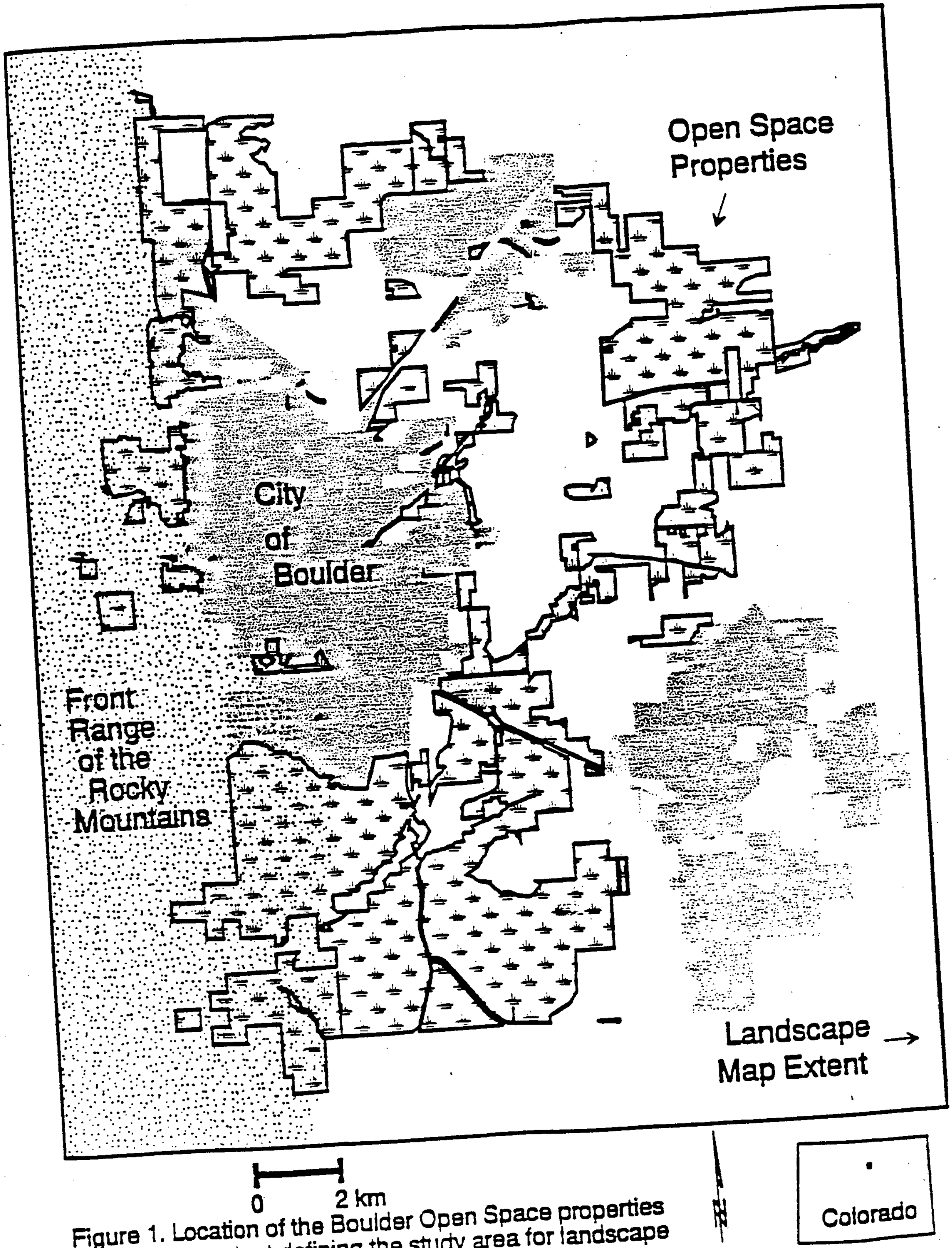



Figure 1. Location of the Boulder Open Space properties and the map extent defining the study area for landscape analysis.

Table 10. Continued.

| Species | Variable tested (scale) | p-value | t | AICC |
|---|---|---|---|---|
| Grasshopper sparrow | hay/pasture (I) | 0.13 | -2.13 | 76.9 |
| | midgrass/shortgrass (I) | | < \|2\| | |
| | hay/pasture (II) | 0.11 | -2.75 | 78.5 |
| | urban (II) | 0.06 | -2.58 | 82.4 |
| | hay/pasture + urban (II) | 0.26 | | 70.3 |
| | hay/pasture (IV) | 0.08 | -2.67 | 80.8 |
| | urban (IV) | 0.07 | -2.67 | 81.6 |
| | hay/pasture (V) | 0.07 | -2.66 | 81.6 |
| | urban (V) | 0.06 | -2.58 | 82.5 |
| Savannah sparrow | tallgrass (I) | 0.77 | 2.64 | 55.5 |
| | tallgrass (II) | 0.77 | 2.62 | 55.5 |
| | tallgrass (III) | 0.79 | 2.76 | 54.7 |
| | tallgrass (IV) | 0.80 | 2.80 | 54.4 |
| | tallgrass (V) | 0.81 | 2.84 | 54.1 |
| | urban (II,III,IV,V) | | < \|2\| | |

Table 11. Models tested in CCA. SUM = sum of all canonical eigenvalues. Variation explained is calculated by dividing SUM by the sum of all eigenvalues from a CA of the species matrix (2.119). For example: model (1): .979 * 100/2.119 = 46.2. Because of constraints in CANOCO, only two matrices could be used in a model. To include all three sets of variables, I created a combined matrix of Habitat type and Landscape composition (V) for models 10, 11, and 12.

| Model Tested | SUM | Variation Explained (%) |
|---|---|---|
| 1) Landscape composition (scale I) | .702 | 33.13 |
| 2) Landscape composition (scale II) | .828 | 39.08 |
| 3) Landscape composition (scale III) | .854 | 40.30 |
| 4) Landscape composition (scale IV) | .919 | 43.37 |
| 5) Landscape composition (scale V) | .979 | 46.20 |
| 6) Habitat type | .560 | 26.43 |
| 7) Landscape composition (V) + Habitat | .185 | 8.73 |
| 8) Habitat + Landscape composition (V) | .604 | 28.50 |
| 9) Location | .827 | 39.03 |
| 10) Habitat/Landscape V | 1.102 | 52.01 |
| 11) Habitat/Landscape V + Location | .275 | 12.98 |
| 12) Location + Habitat/Landscape V | .545 | 25.72 |

Table 12. Relative contribution of landscape, habitat, and location variables toward explaining the variation in the bird species abundance data. Percent of variation explained is calculated from Variation Explained by individual models in Table 11.

| Component of variation<br>Models including Landscape V and Habitat type | Percent of variation explained | Formula (from values in Table 12) |
|---|---|---|
| Landscape context (composition, scale V) | 28.50 | (8) |
| Collinearity: Habitat and Landscape V | 17.70 | (5) - (8) |
| Habitat type | 8.73 | (7) |
| Unexplained | 45.50 | 100 - ((5) + (7)) |

| Component of variation<br>Models including Habitat/Landscape V and Habitat type | Percent of variation explained | Formula (from values in Table 12) |
|---|---|---|
| Landscape V/Habitat (combined matrix) | 25.72 | (12) |
| Common spatial structure (collinearity) | 26.29 | (10) - (12) |
| Space | 12.98 | (11) |
| Unexplained | 35.01 | 100 - ((10) + (11)) |

Figure 1. Map extent for analysis of landscape pattern in grasslands and urban areas near Boulder, Colorado. The stippled area on the western edge represents the Front Range of the Rocky Mountains. The polygons surrounding the city of Boulder are Open Space properties. Urban areas are shaded.

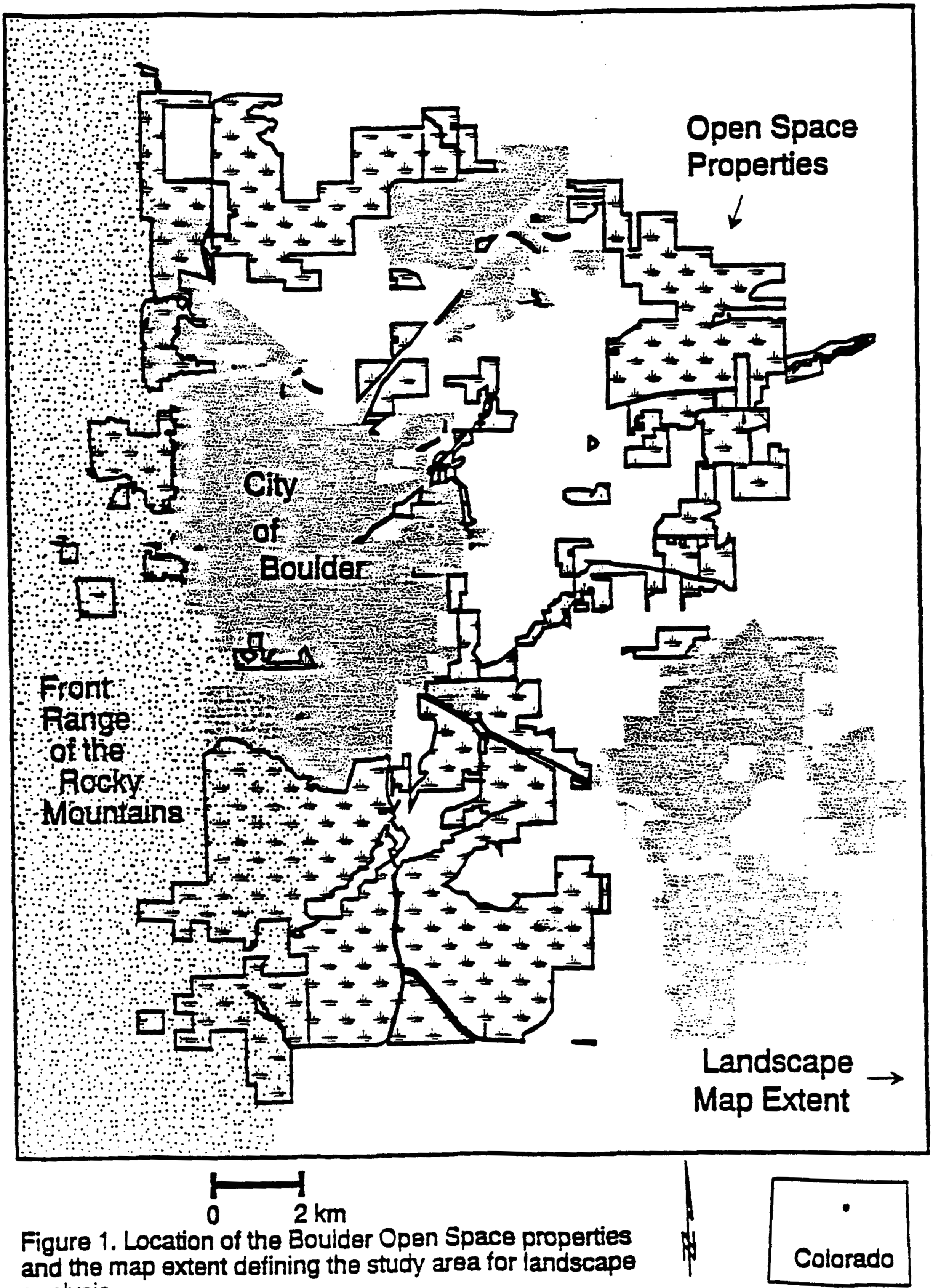
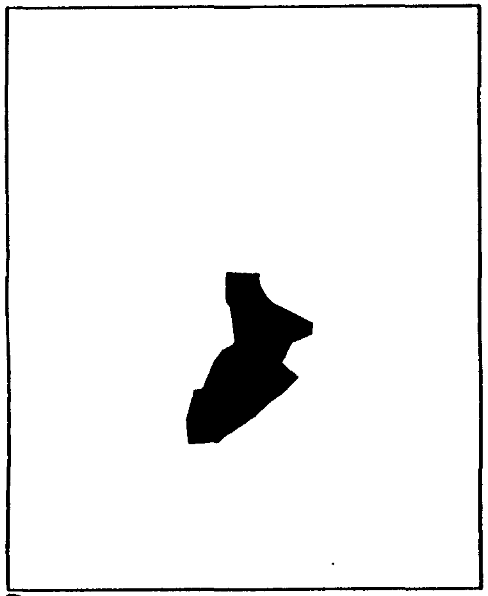
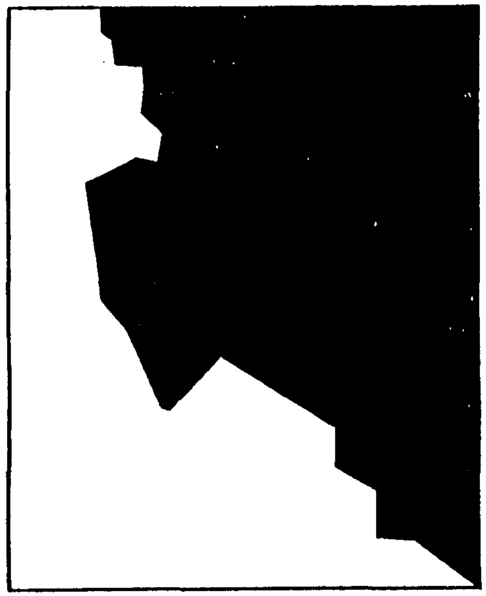


Figure 1. Location of the Boulder Open Space properties and the map extent defining the study area for landscape analysis.

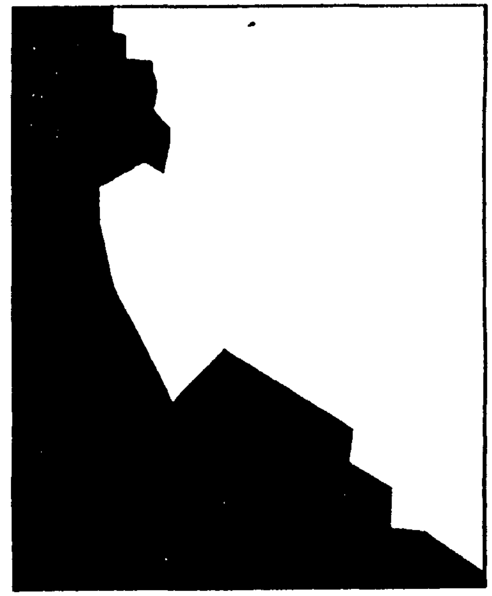
Figure 2. Three masks were used to aid in classification of the satellite image. The tallgrass mask included the area southwest of the city of Boulder, where most of the native tallgrass areas occur. The northeast mask covered the urban and suburban areas and the agricultural regions in the northeastern portion of the study area. The southwest mask included the foothills and the upland grassland areas to the south and north of the city of Boulder.



Tallgrass Mask



Northeast Mask



Southwest Mask

Figure 3. Example of an ordination diagram. This simplified ordination diagram shows one gradient, represented by a line that is proportional to its importance to the ordination. The mean of the gradient occurs at the origin. The lower end of the gradient (not shown in most diagrams) is represented by a dashed line. Species points (shown as dots) are located in the center of the species' distribution along the gradient. A perpendicular line drawn from the species point to the gradient line locates the center of the species distribution for each species along any gradient in the diagram.

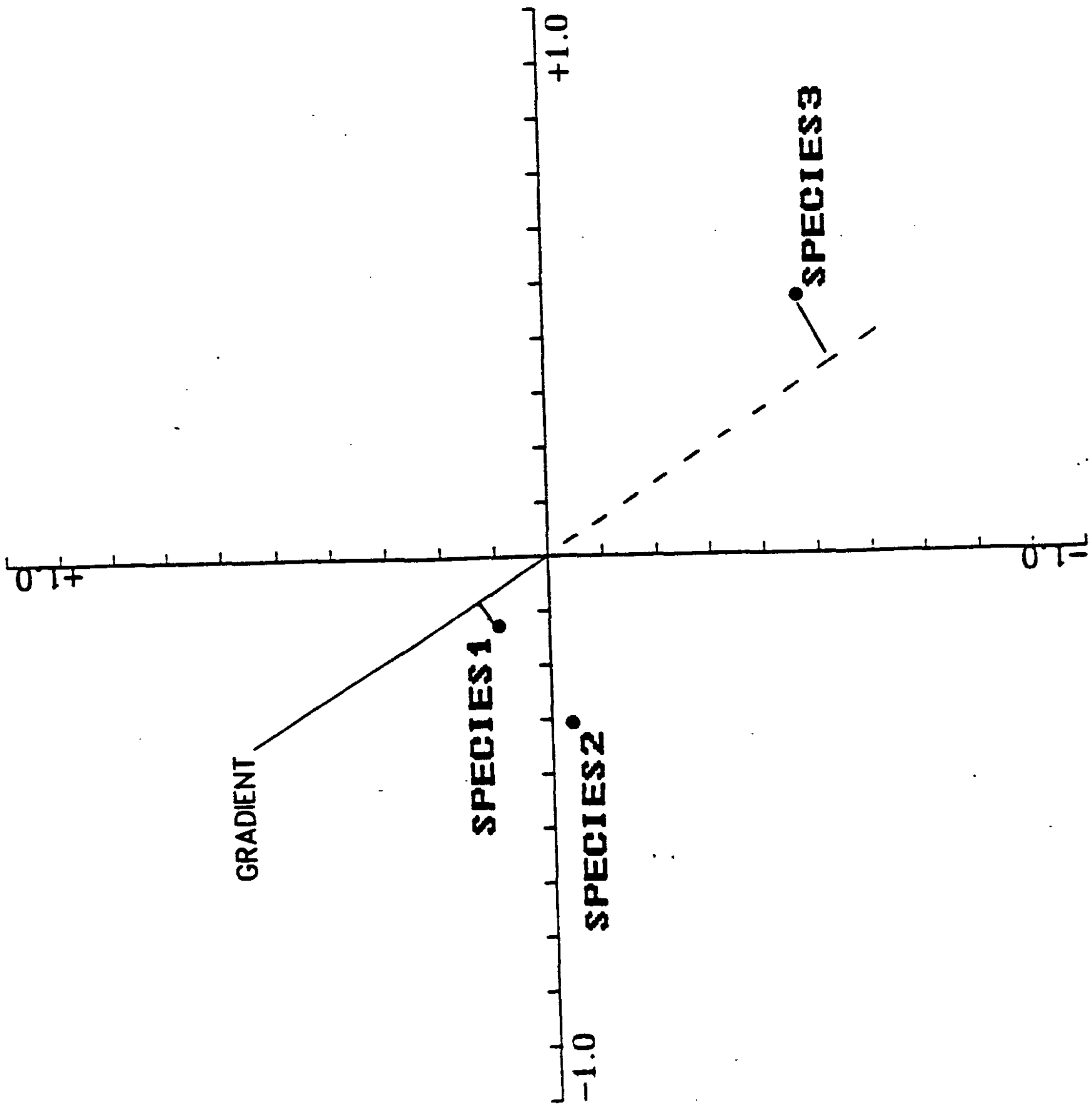

+1.0
-1.0
+1.0
-1.0
SPECIES3
SPECIES1
SPECIES2
GRADIENT

Figure 4. Land cover map of the study area, including Boulder, Colorado Open Space grasslands and surrounding landscape. The map legend is shown on the following page.

Scale

5 0 Kilometers

2 0 2 Miles

Class_Names

Water
Conifer
Ponderosa pine shrub/savanna
Midgrass/mixed grass

Class_Names

Wetland/riparian
Midgrass/shortgrass
Non-native hay/pasture
Ponerosa pine forest/woodland
Shrubs

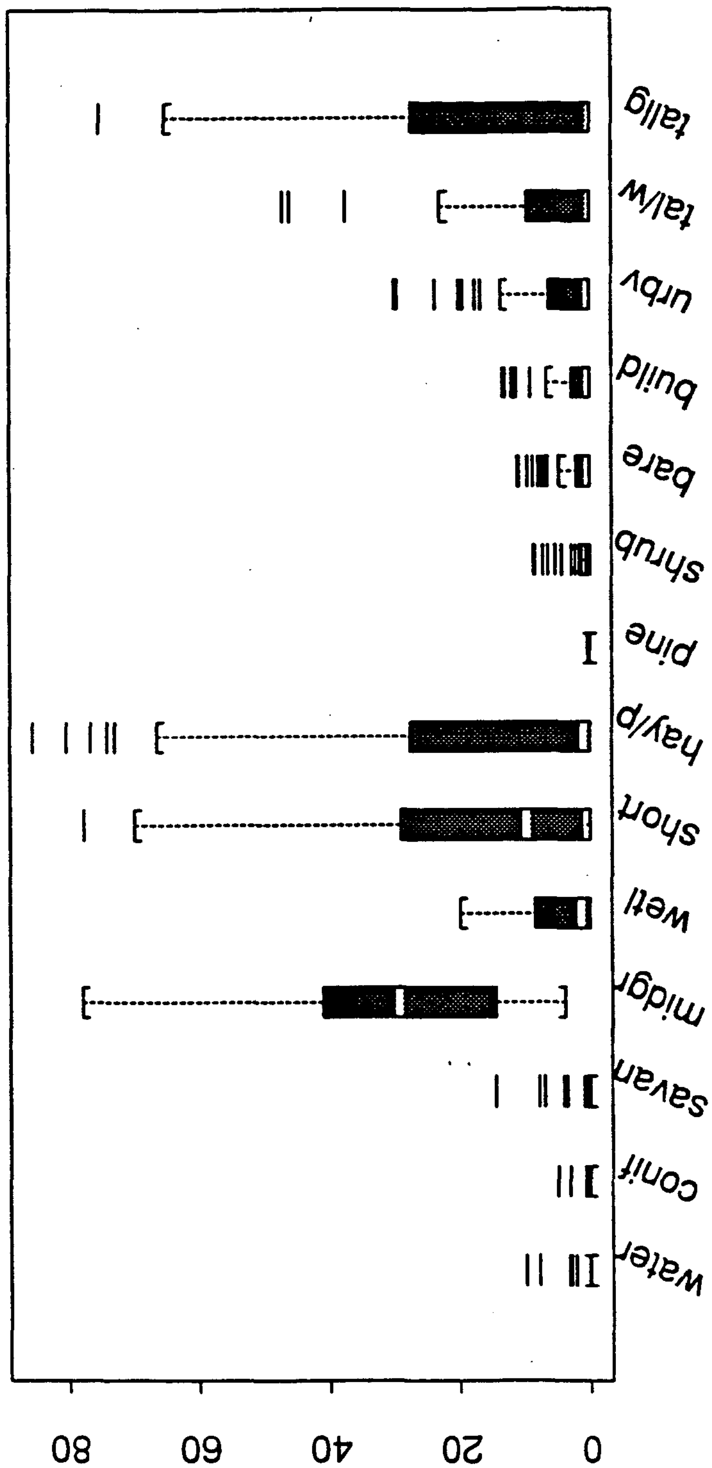
Class_Names

Bare rock/soil
Buildings/paved
Urban vegetation
Native tallgrass (wetter)
Native tallgrass (drier)

Figure 5a. Box plots of cover type distribution at scale I. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.

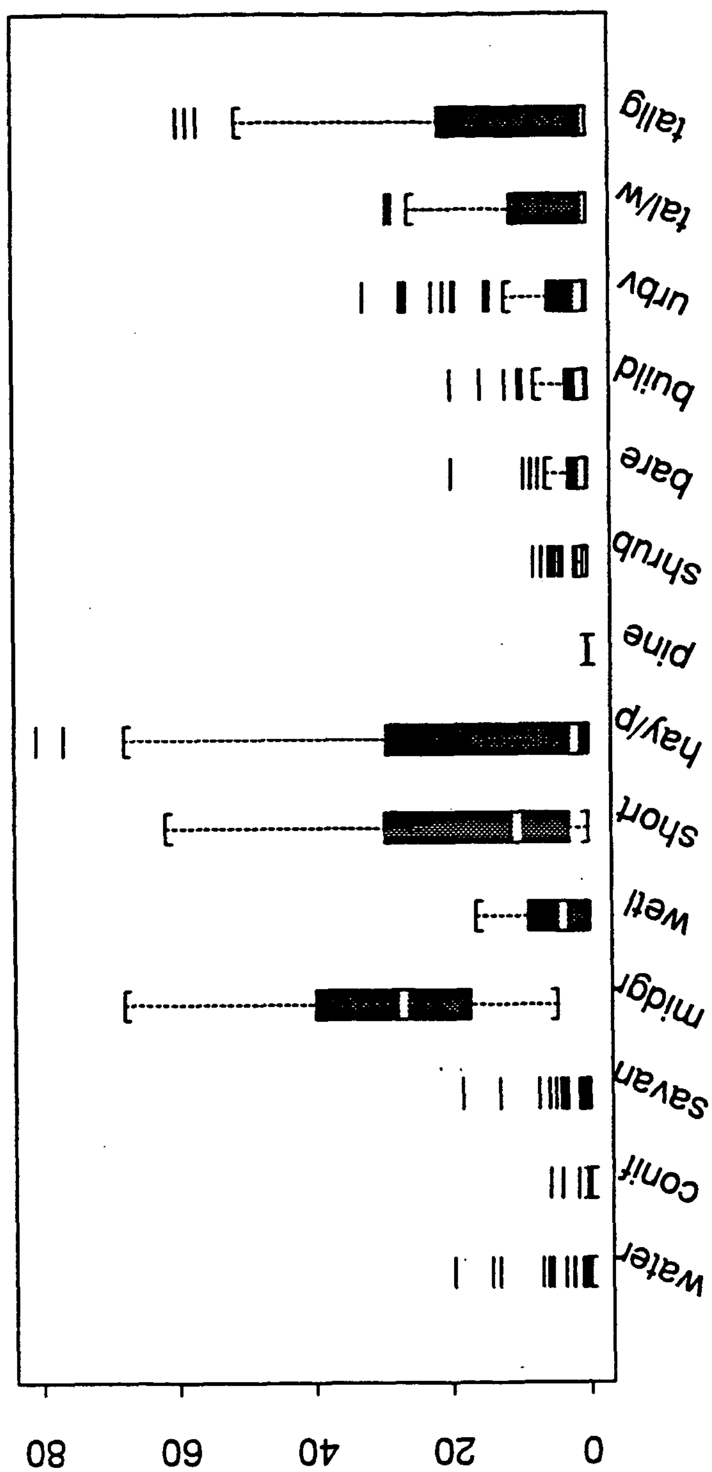

tallg
tal/w
urbv
build
bare
shrub
pine
hay/p
short
wetl
midgr
savan
conif
water
0
20
40
60
80
100

Figure 5b. Box plots of cover type distribution at scale II. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.



tallg
tal/w
urby
build
bare
shrub
pine
hay/p
short
wetl
midgr
savan
conif
water
0
20
40
60
80

Figure 5c. Box plots of cover type distribution at scale III. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.



water
conif
savan
midgr
wetl
short
hay/p
pine
shrub
bare
build
urbv
tal/w
tallg
0
20
40
60
80

Figure 5d. Box plots of cover type distribution at scale IV. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.

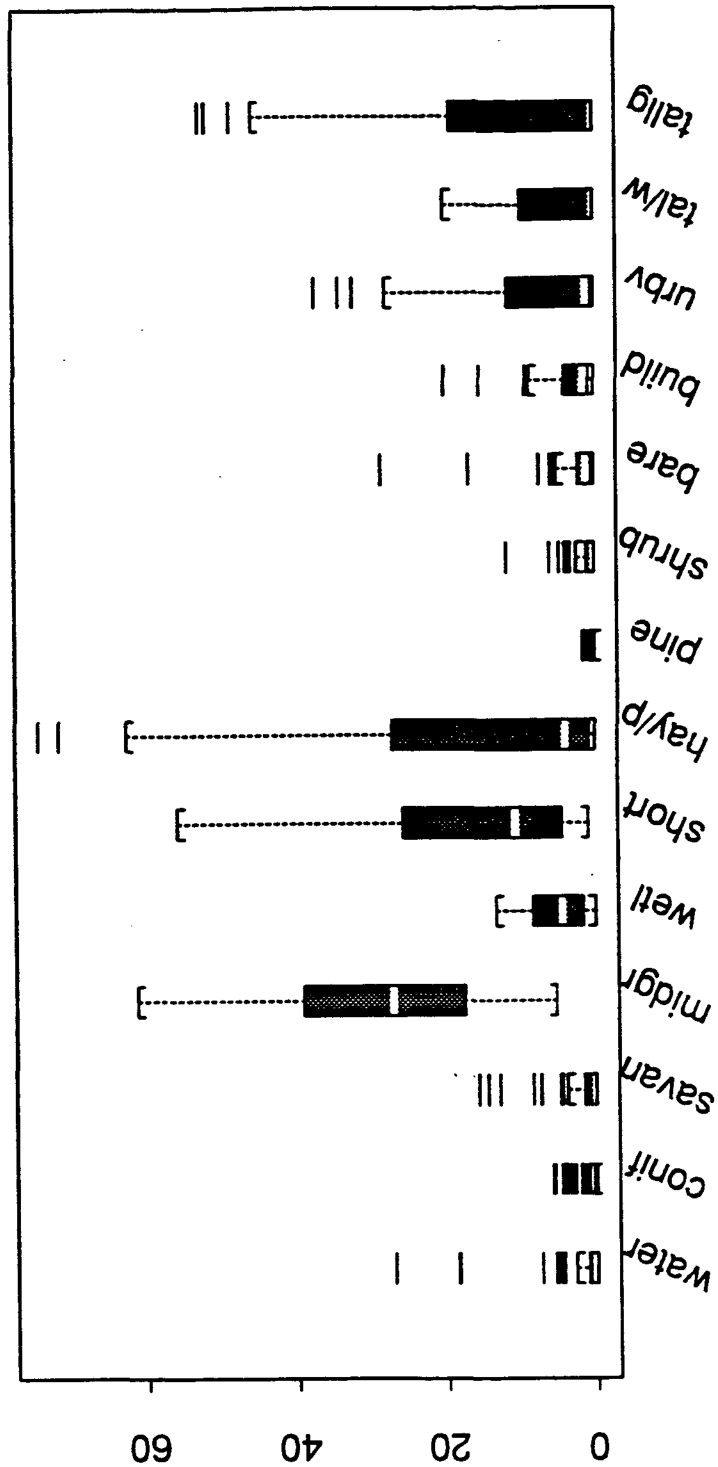

tallg
tal/w
urbv
build
bare
shrub
pine
hay/p
short
wetl
midgr
savan
conif
water
0
20
40
60

Figure 5e. Box plots of cover type distribution at scale V. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.

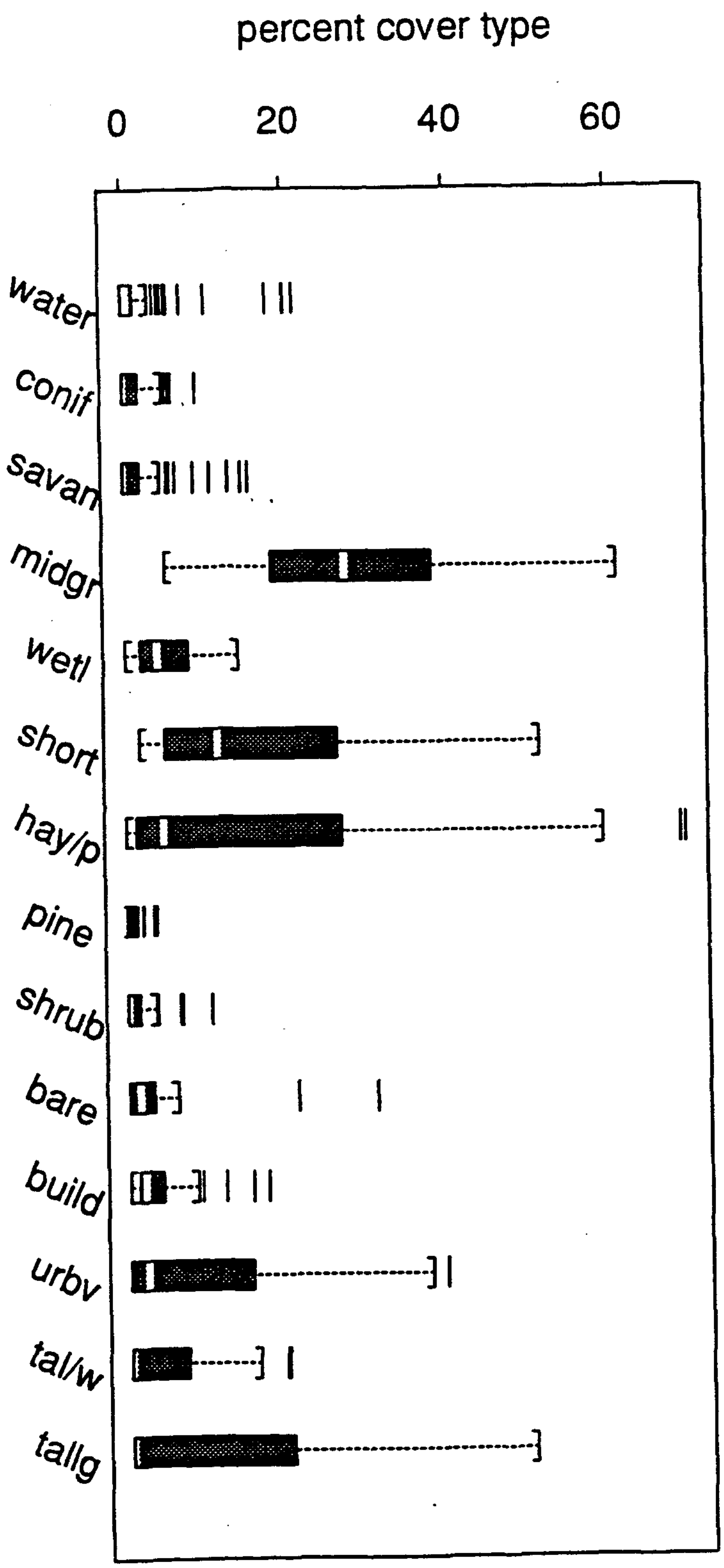

percent cover type
0
20
40
60
water
conif
savan
midgr
wetl
short
hay/p
pine
shrub
bare
build
urbv
tal/w
tallg

Figure 6. Distribution of urban cover types at five scales of analysis. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.

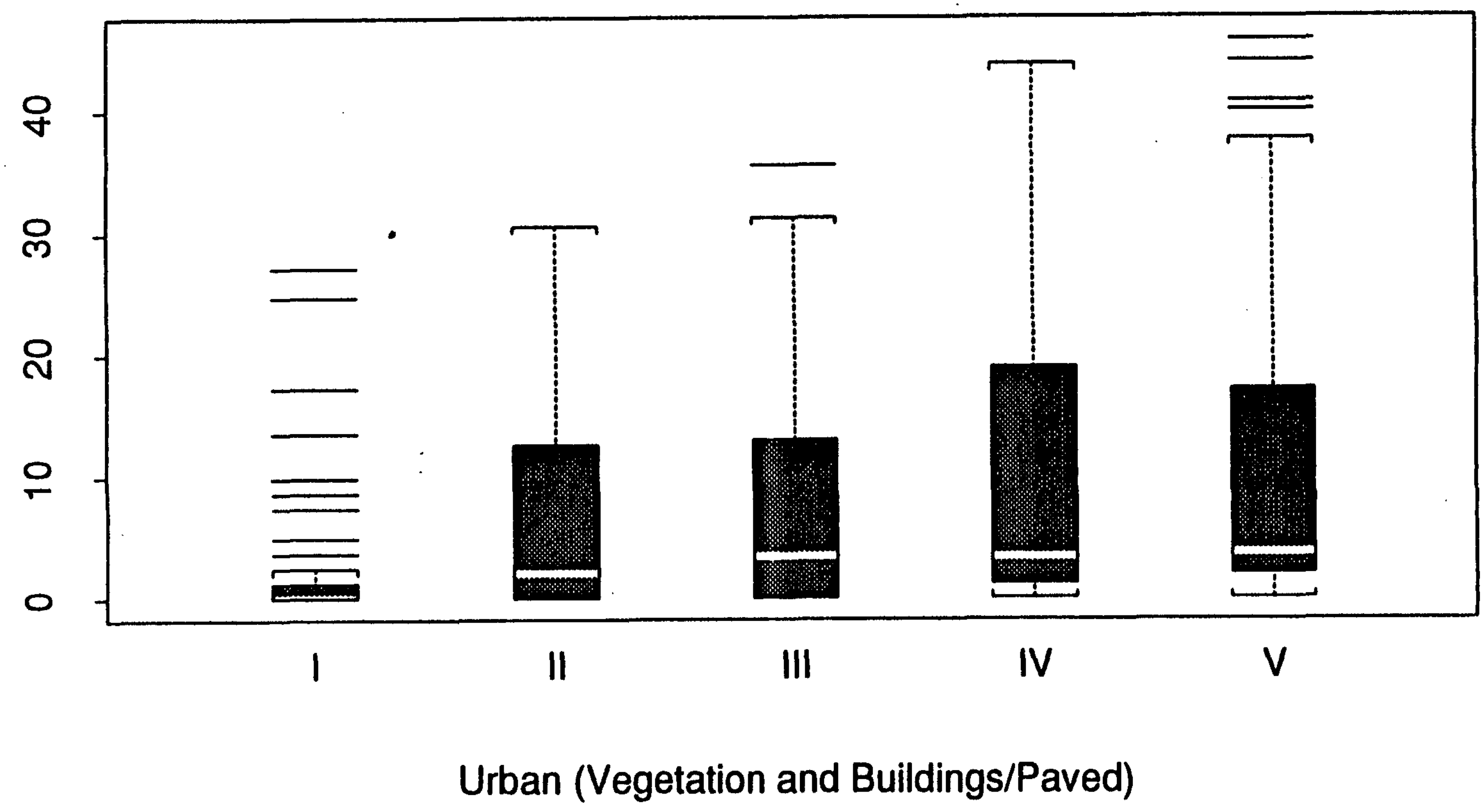
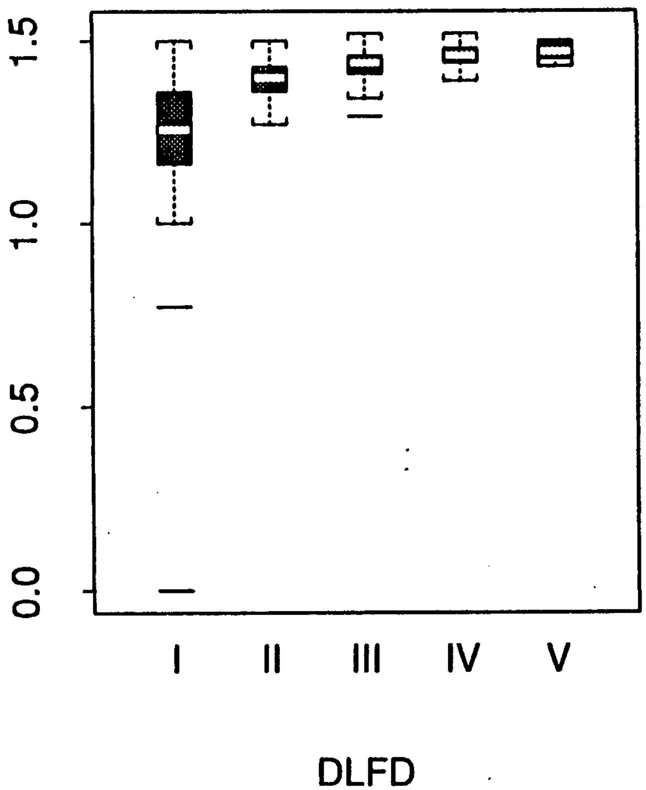
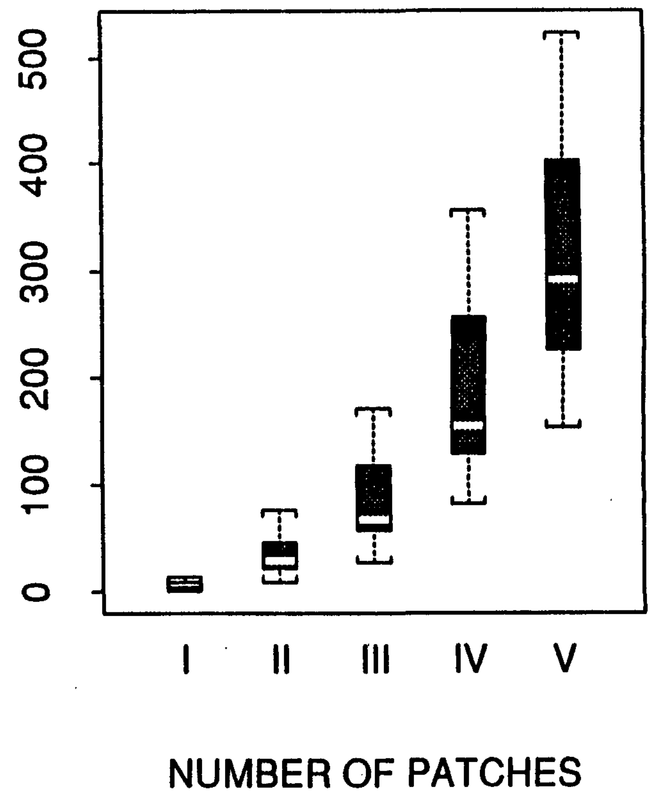

percent
0
10
20
30
40
I
II
III
IV
V
Urban (Vegetation and Buildings/Paved)

Figure 7a. - 7b. Distribution of landscape configuration indices at five scales of analysis. The horizontal line in the interior of the box is located at the median of the data. The whiskers extend to the extreme values of the data.



0.0
0.5
1.0
1.5
I
II
III
IV
V
DLFD

0
100
200
300
400
500
I
II
III
IV
V
NUMBER OF PATCHES

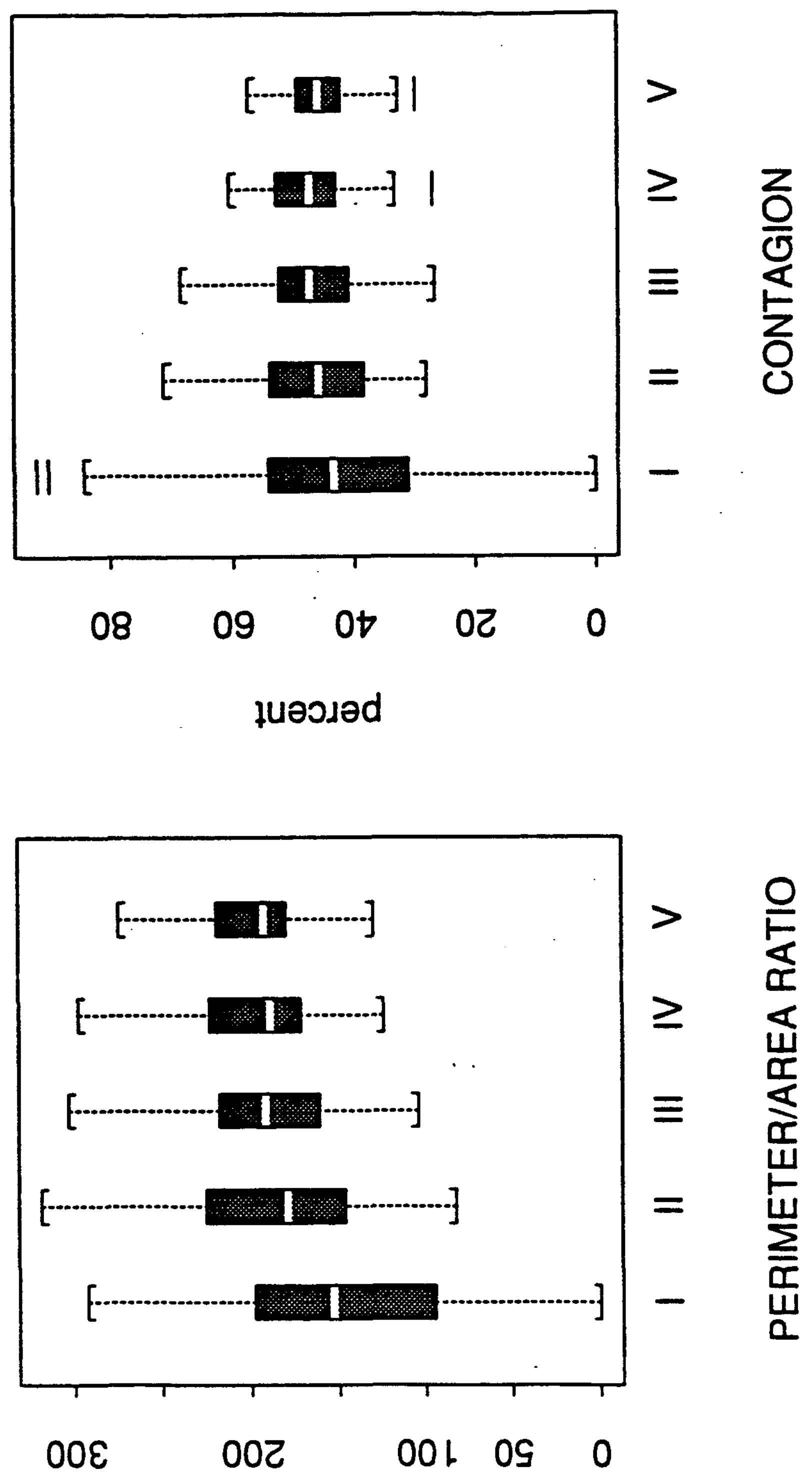
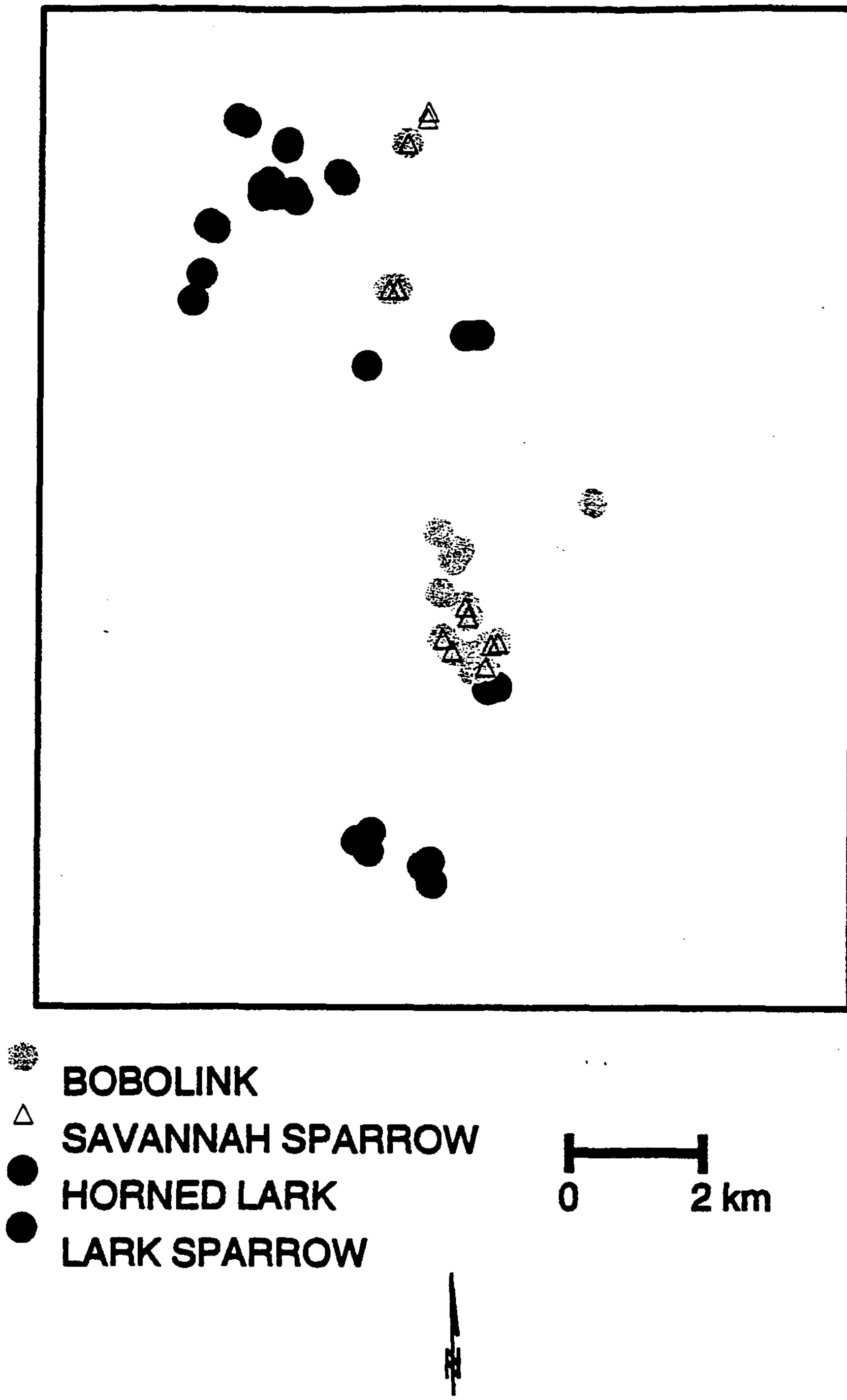
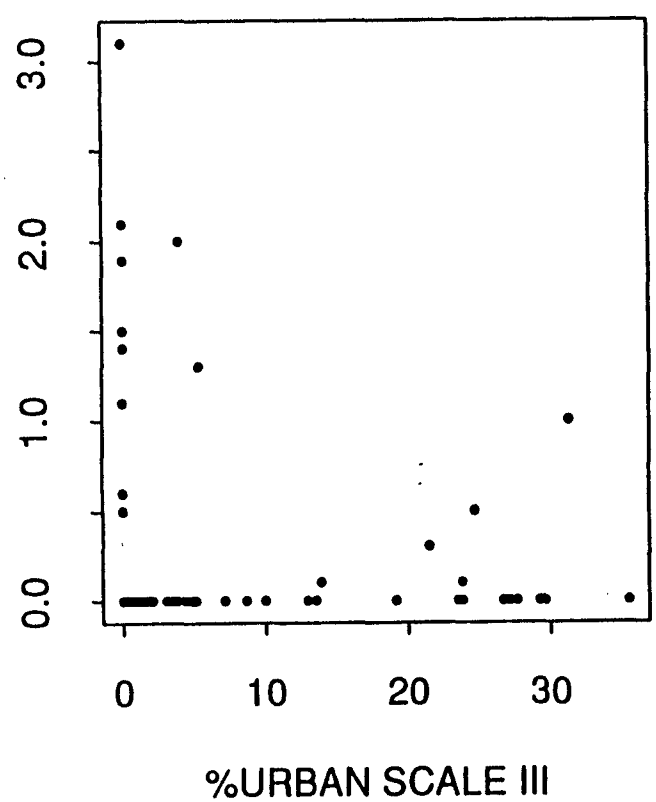
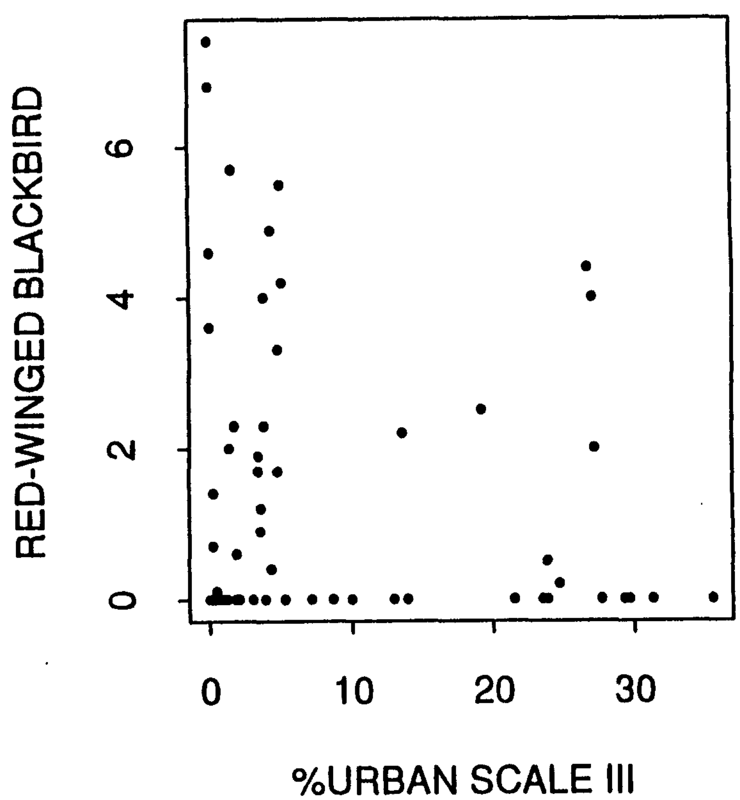
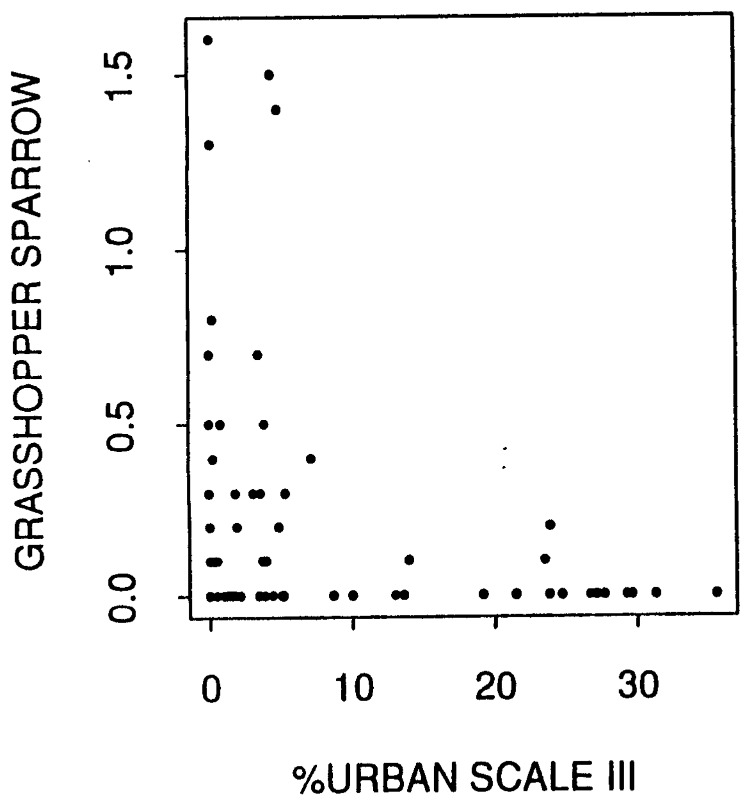

CONTAGION
percent
0
20
40
60
80
I
II
III
IV
V
PERIMETER/AREA RATIO
0
50
100
200
300

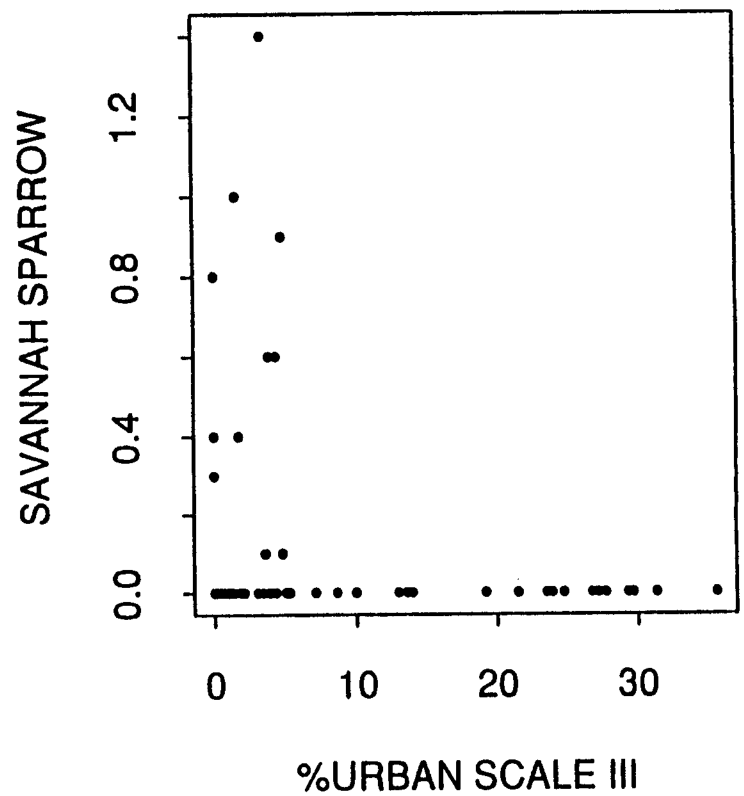
Figure 8. Geographic distribution of four grassland bird species in the study area. The Savannah Sparrow and Bobolink overlapped in distribution, but were only observed in tallgrass or hayfield plots. The Lark Sparrow and the Horned lark occurred exclusively in mixed grass and shortgrass plots, but were never observed at the same plots.

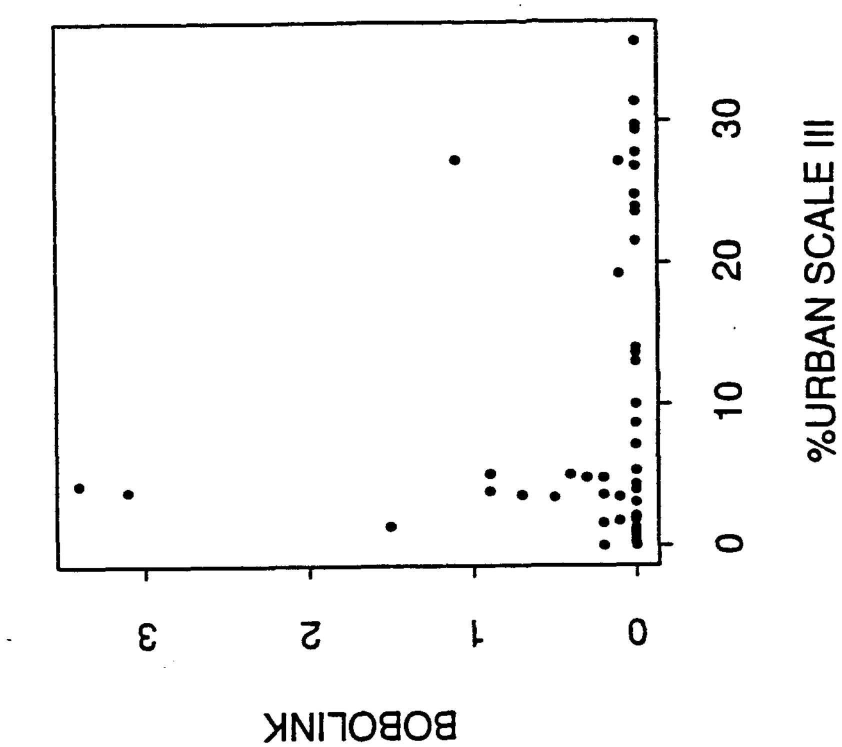

BOBOLINK
SAVANNAH SPARROW
HORNED LARK
LARK SPARROW
0
2 km
N

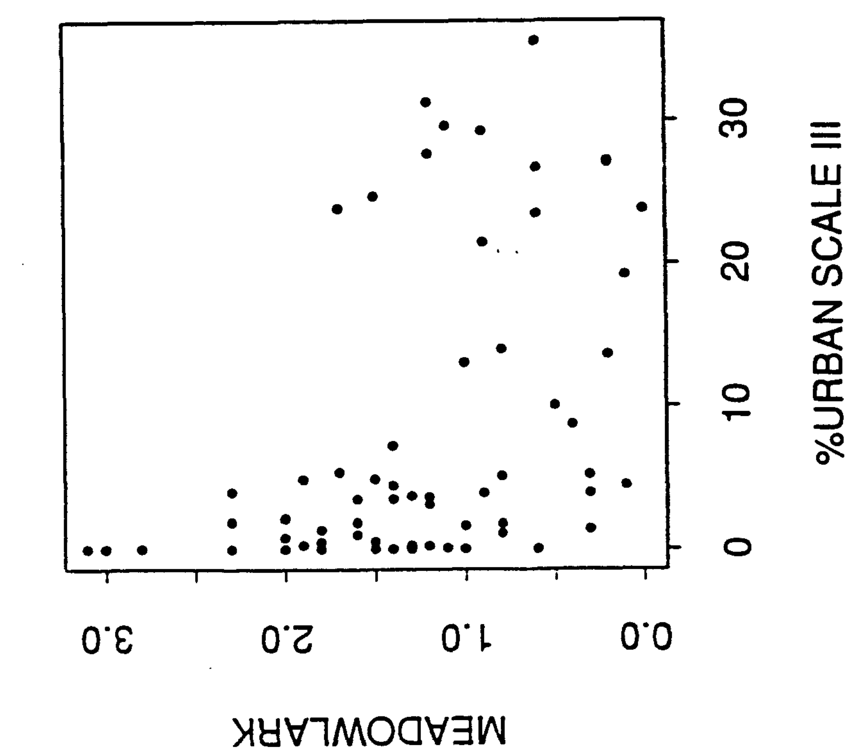

LARK SPARROW
0.0
1.0
2.0
3.0
0
10
20
30
%URBAN SCALE III


RED-WINGED BLACKBIRD
0
2
4
6
0
10
20
30
%URBAN SCALE III

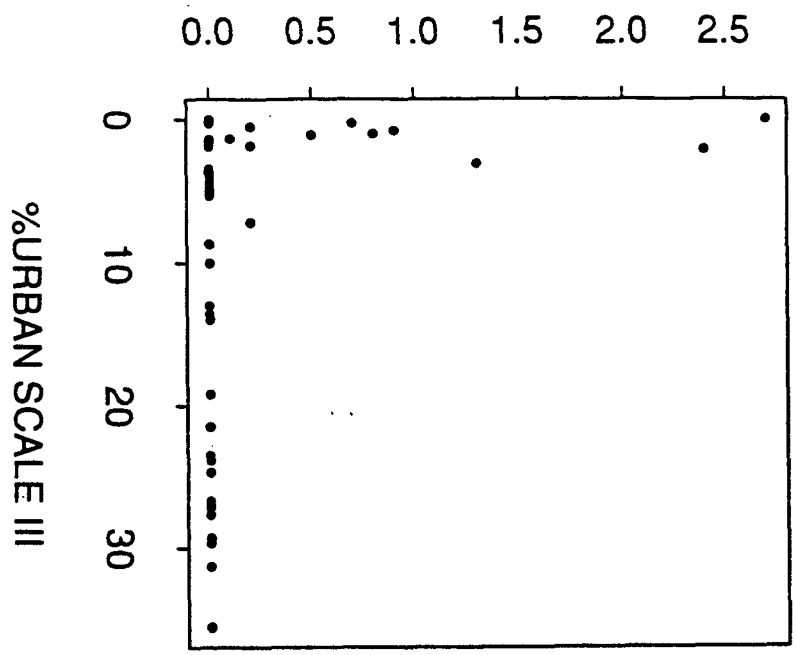

GRASSHOPPER SPARROW
0.0
0.5
1.0
1.5
%URBAN SCALE III
0
10
20
30


SAVANNAH SPARROW
0.0
0.4
0.8
1.2
%URBAN SCALE III
0
10
20
30


BOBOLINK
0
1
2
3
%URBAN SCALE III
0
10
20
30


MEADOWLARK
0.0
1.0
2.0
3.0
%URBAN SCALE III
0
10
20
30

HORNED LARK




VESPER SPARROW

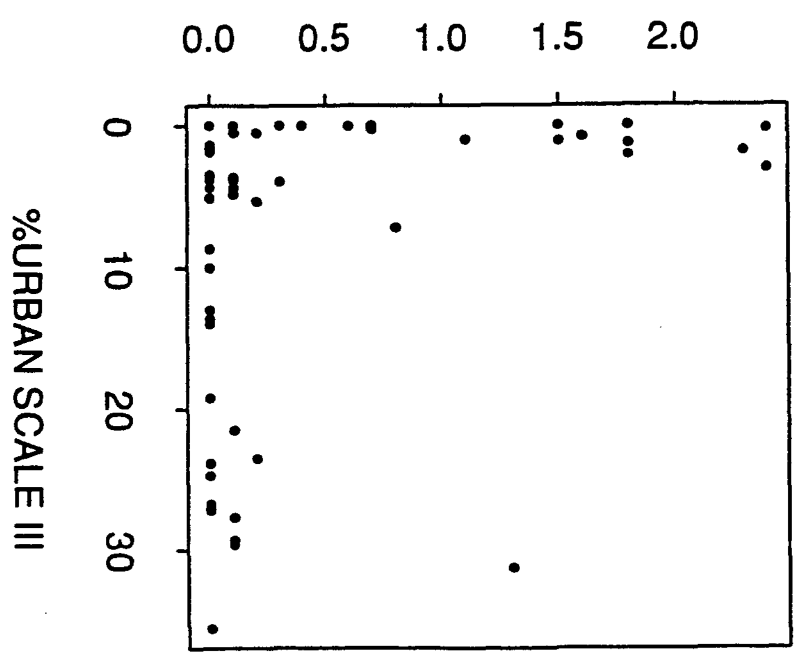
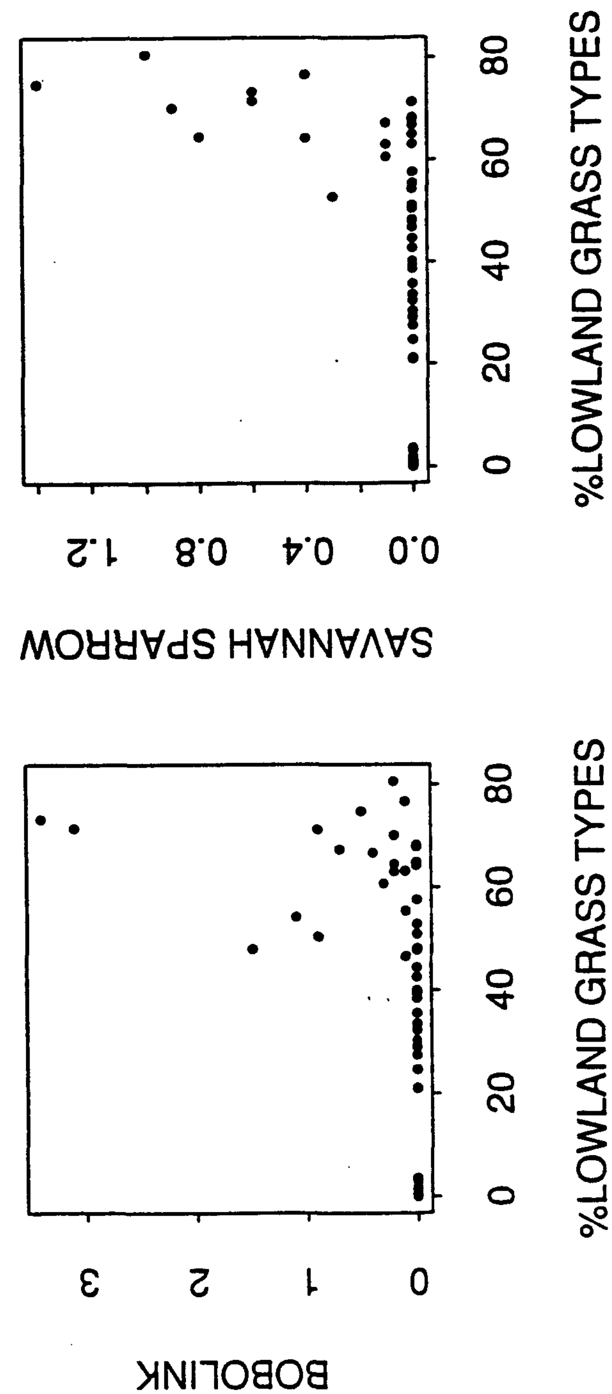


Figure 10. Scatter plots of Bobolink, Savannah Sparrow, Lark Sparrow and Horned Lark abundance (y-axis) and percent lowland or upland grassland in the landscape at scale III. The first two species occurred only in lowland types, and the latter two occurred only in upland grass types. This association carried over in the species' relationships to landscape pattern.



SAVANNAH SPARROW
0.0
0.4
0.8
1.2
0
20
40
60
80
%LOWLAND GRASS TYPES
BOBOLINK
0
1
2
3
0
20
40
60
80
%LOWLAND GRASS TYPES

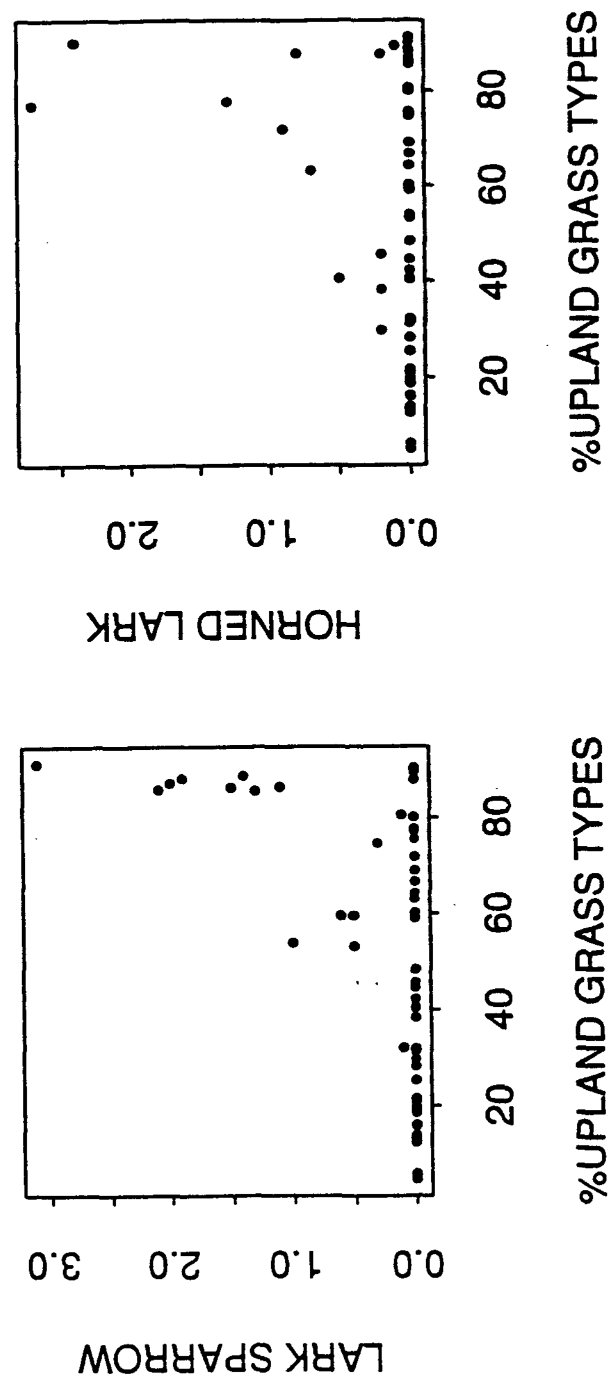
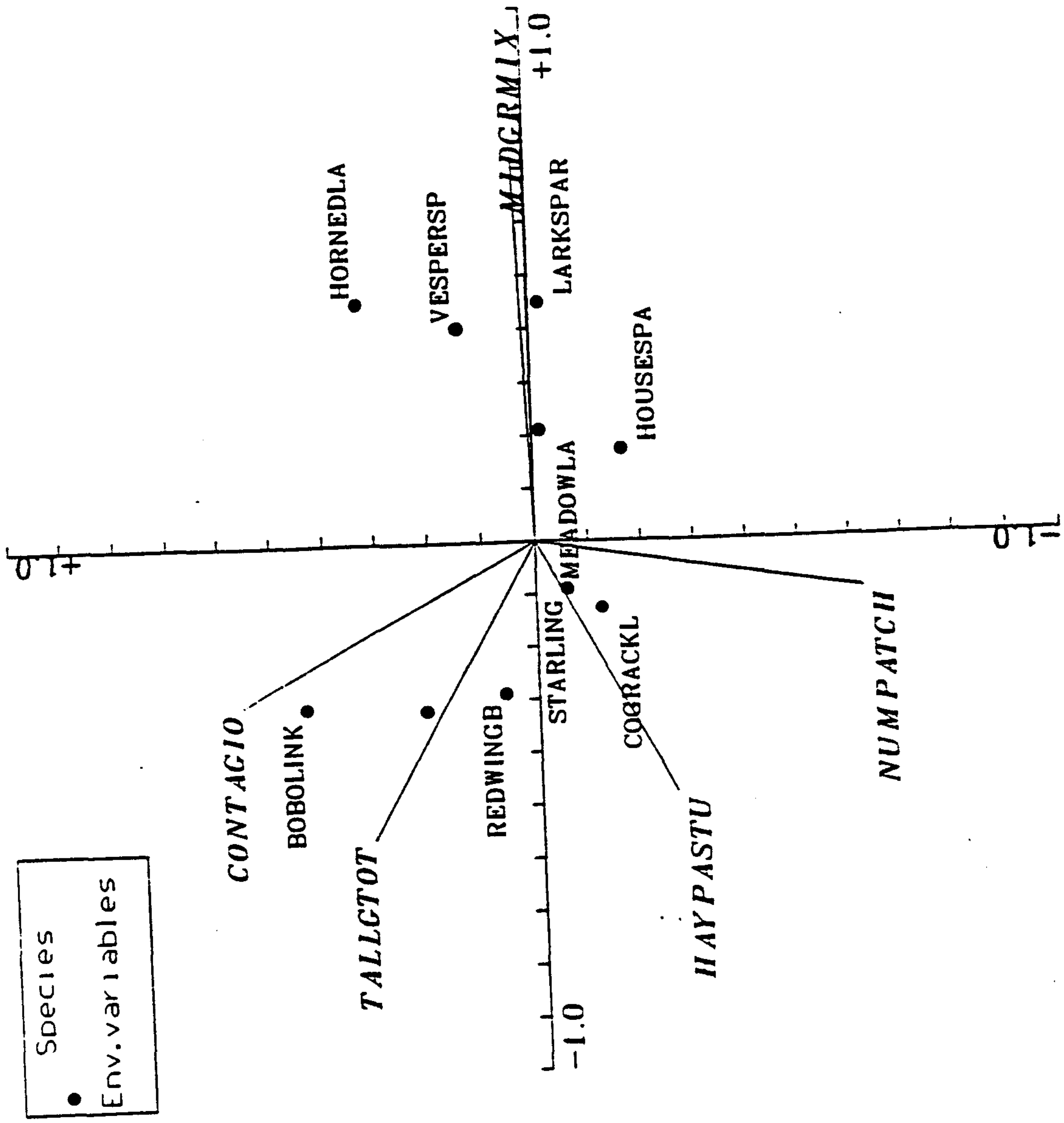

HORNED LARK
0.0
1.0
2.0
20
40
60
80
%UPLAND GRASS TYPES
LARK SPARROW
0.0
1.0
2.0
3.0
20
40
60
80
%UPLAND GRASS TYPES

Figure 11a. Ordination diagram resulting from CCA analysis using variables selected with forward selection at scale I. Species points are dots, and lines represent gradients identified in the ordination. The eigenvalues were 0.485 (axis 1) and 0.145 (axis 2). CONTAGIO = Contagion, TALLGTOT = Tallgrass (percent composition), HAYPASTU = Non-native hay/pasture (percent composition), NUMPATCH = Number of patches, MIDGRMIX = Midgrass/mixed grass. See Table 1. for bird species names. Midgrass/shortgrass gradient is coincident with midgrass/mixed grass at scale I. Four species points are not labelled: Savannah Sparrow species point is located on the TALLGTOT gradient, House Finch and American Robin are located by the Starling, and Grasshopper Sparrow is located by the Lark Sparrow.



+1.0
-1.0
+1.0
-1.0
MIDGRMIX
HORNEDLA
VESPERSP
LARKSPAR
HOUSESPA
MEADOWLA
STARLING
COGRACKL
NUMPATCH
HAYPASTU
REDWINGB
TALLGTOT
BOBOLINK
CONTAGIO
Species
Env.variables

Figure 11b. Ordination diagram resulting from CCA analysis using variables selected with forward selection at scale III. Species points are dots, and lines represent gradients identified in the ordination. The eigenvalues were 0.487 (axis 1) and 0.195 (axis 2). URBANTOT = Urban cover types (percent composition), MIDGSHOR = Midgrass/shortgrass. House Finch species point occurs near the Grackle point.

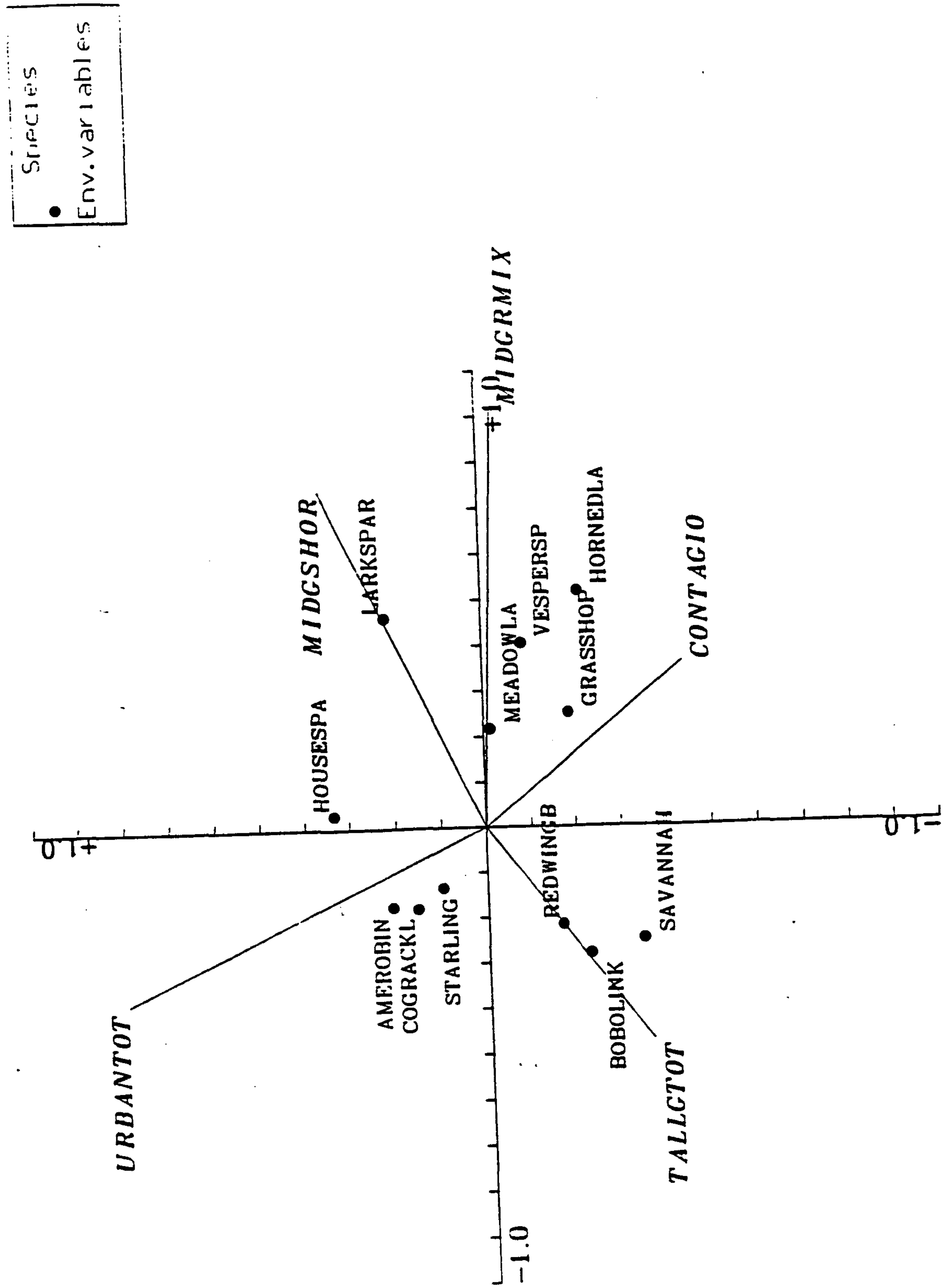
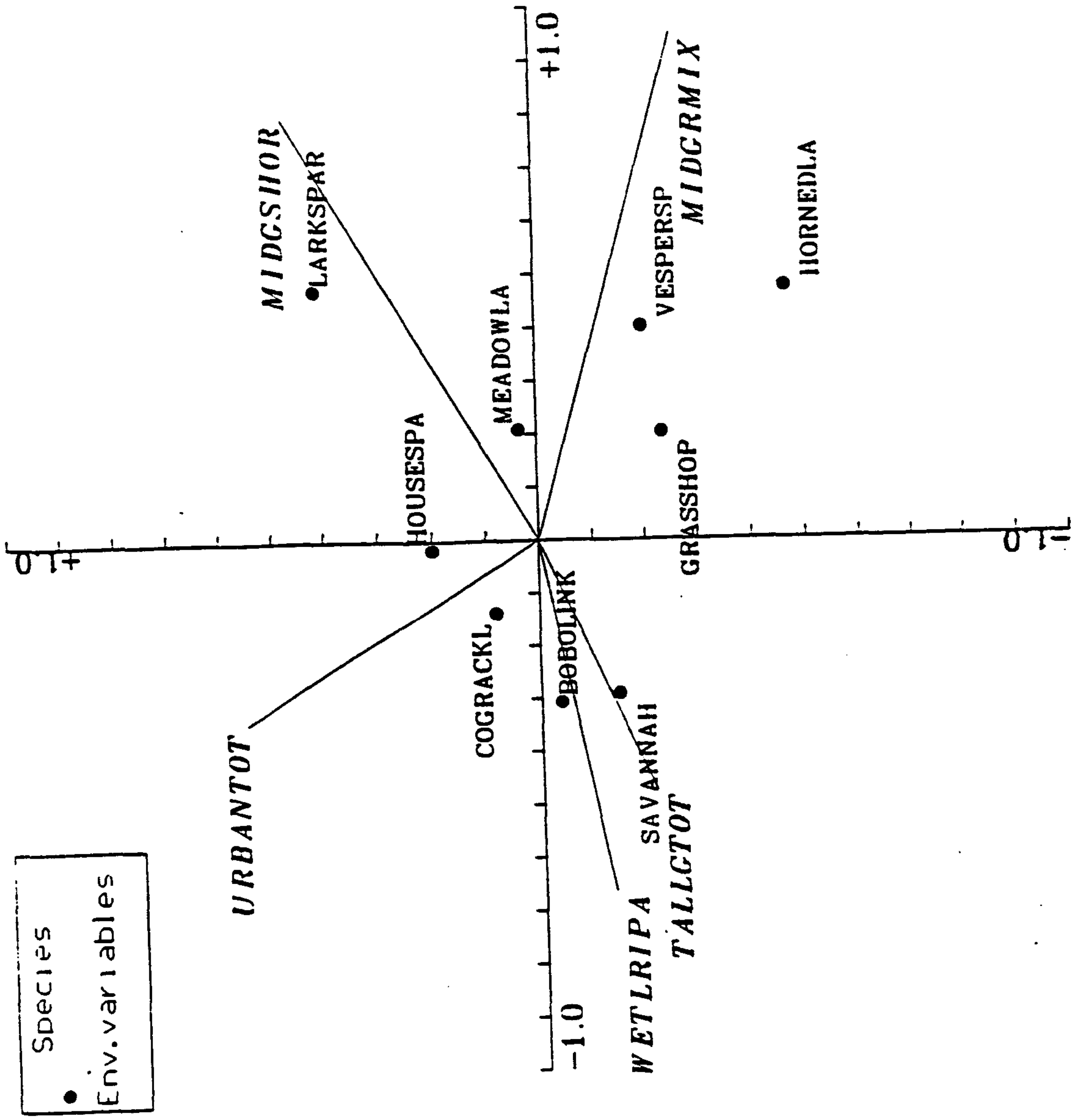

Species
Env. variables
+1.0
-1.0
MIDGRMIX
MIDGSHOR
CONTAGIO
URBANTOT
TALLCTOT
LARKSPAR
HOUSESPA
MEADOWLA
VESPERSP
HORNEDLA
GRASSHOP
REDWINGB
SAVANNA
BOBOLINK
STARLING
AMEROBIN
COGRACKL

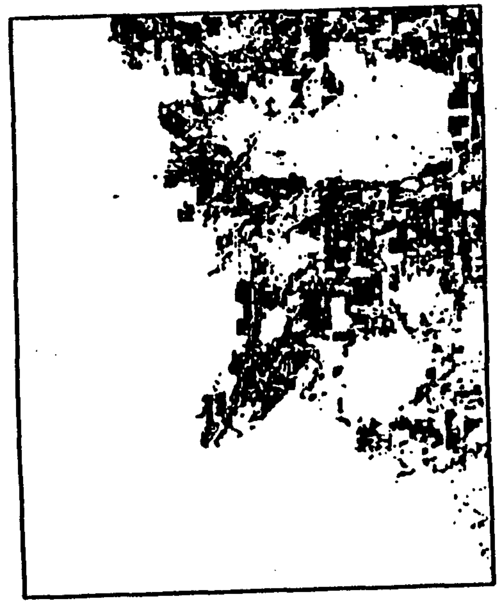
Figure 11c. Ordination diagram resulting from CCA analysis using variables selected with forward selection at scale V. Species points are dots, and lines represent gradients identified in the ordination. The eigenvalues were 0.471 (axis 1) and 0.211 (axis 2). WETLRIPA = Wetland/riparian (percent composition). Red-winged blackbird point is near Bobolink, Starling, Robin and House Finch points are very close to Grackle.



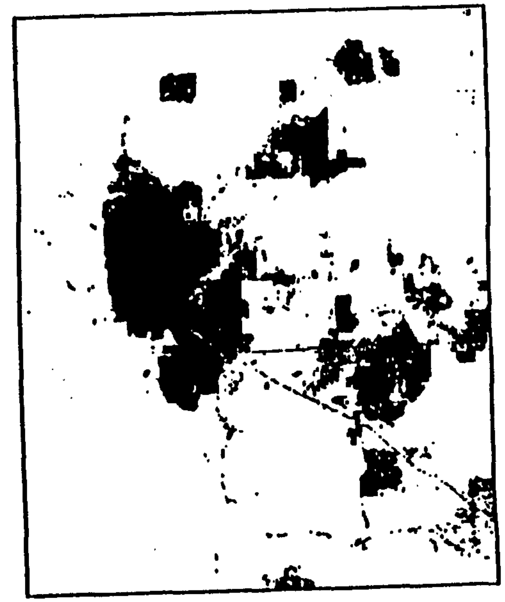
+1.0
-1.0
MIDGSHOR
LARKSPAR
MEADOWLA
HOUSESPA
VESPERSP
MIDGRMIX
HORNEDLA
GRASSHOP
BOBOLINK
COGRACKL
SAVANNAH
TALLGTOT
WETLRIPA
URBANTOT
Species
Env.variables

Figure 12. Spatial patterns of grassland and urban cover types. Upland grasslands (mixed grass and shortgrass) occur in large contiguous areas in the south-central and north-eastern areas of the map. Non-native hay/pasture cover types are restricted to the northeastern portion of the map, and tallgrass extends into the central area, just southeast of Boulder. The development of urban areas has occurred in a large, central area, and in several smaller clusters across the landscape.

Mixed grass/Shortgrass

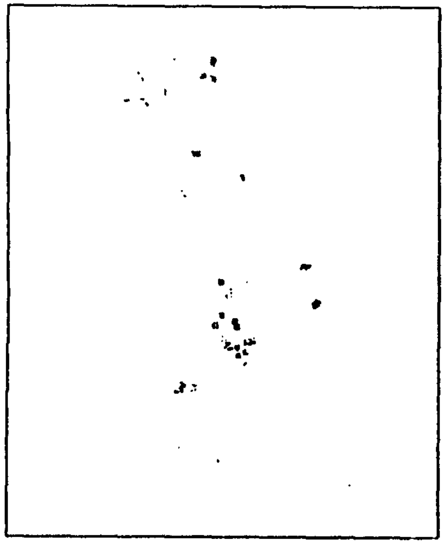


Lowland Hay/Tallgrass

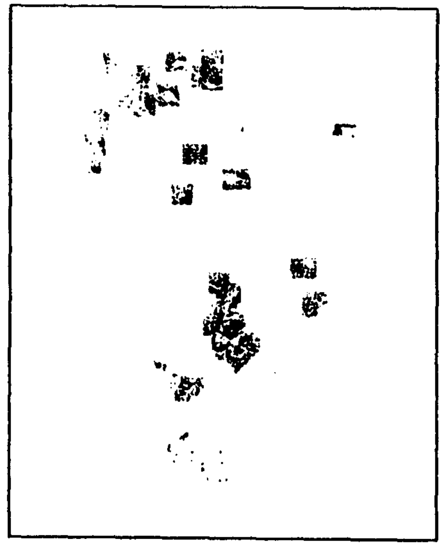


Urban Cover types

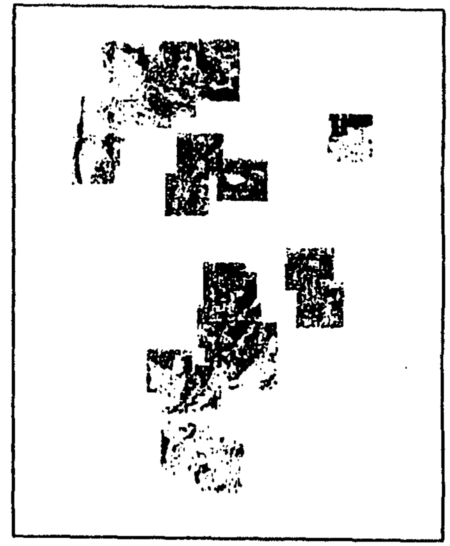
Figure 13. Analysis windows are fairly distinct from each other at scale I, but an increasing amount of overlap occurs at scales III and V. This contributes to an averaging effect at coarser scales.



Scale I (6 ha)

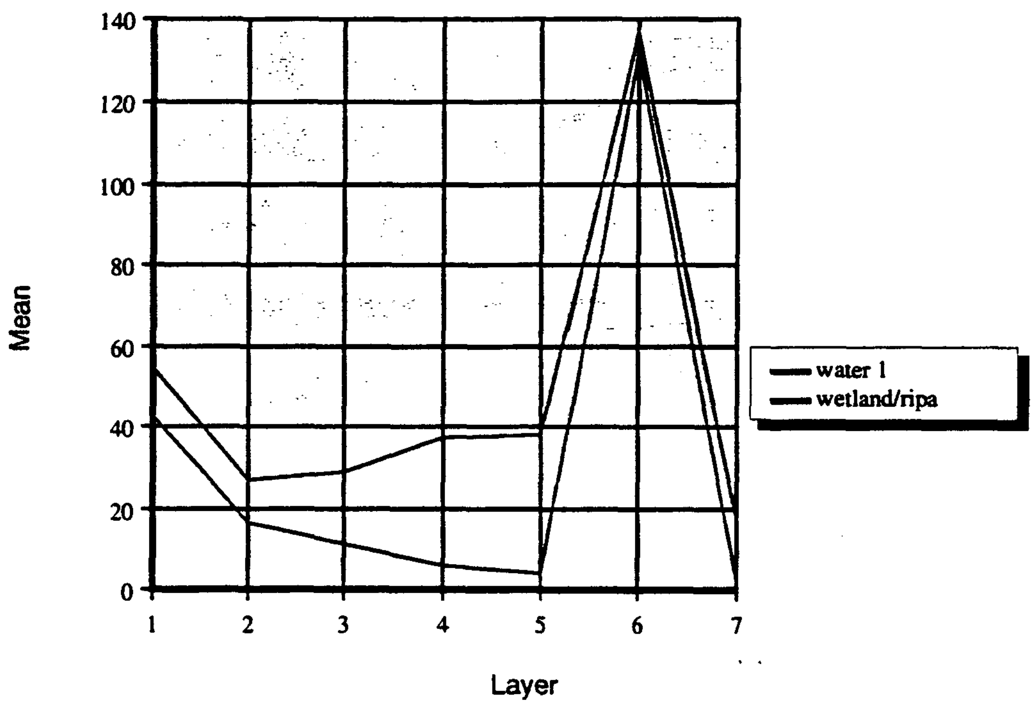


Scale III (103 ha)

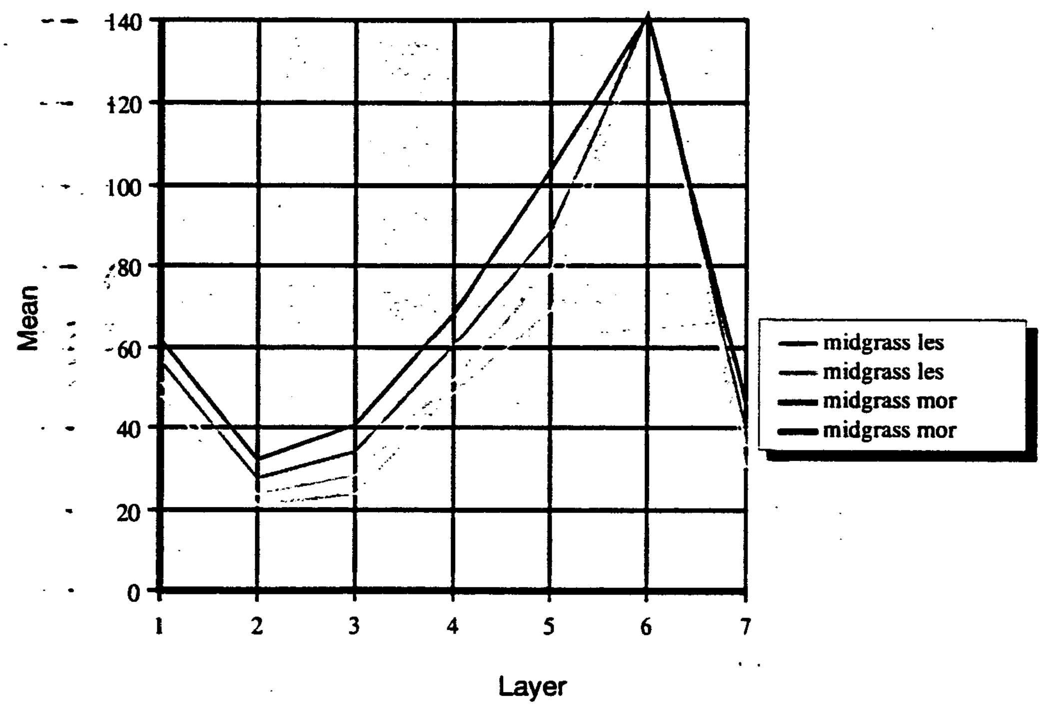


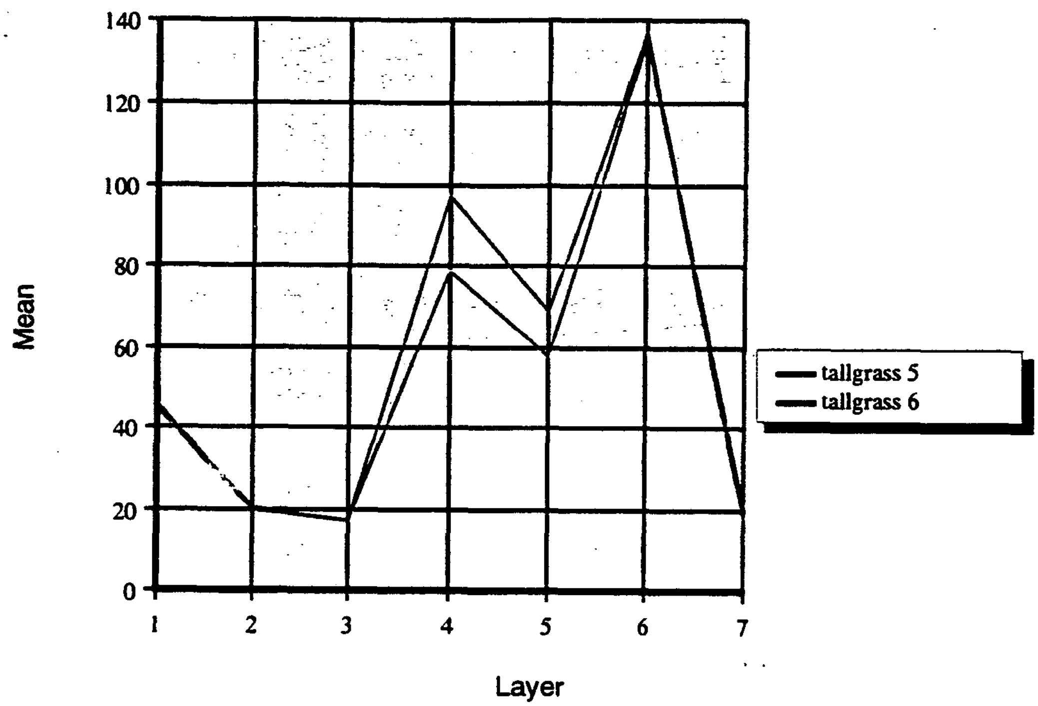
Scale V (423 ha)

Appendix 1. Examples of signature plots used in image classification.

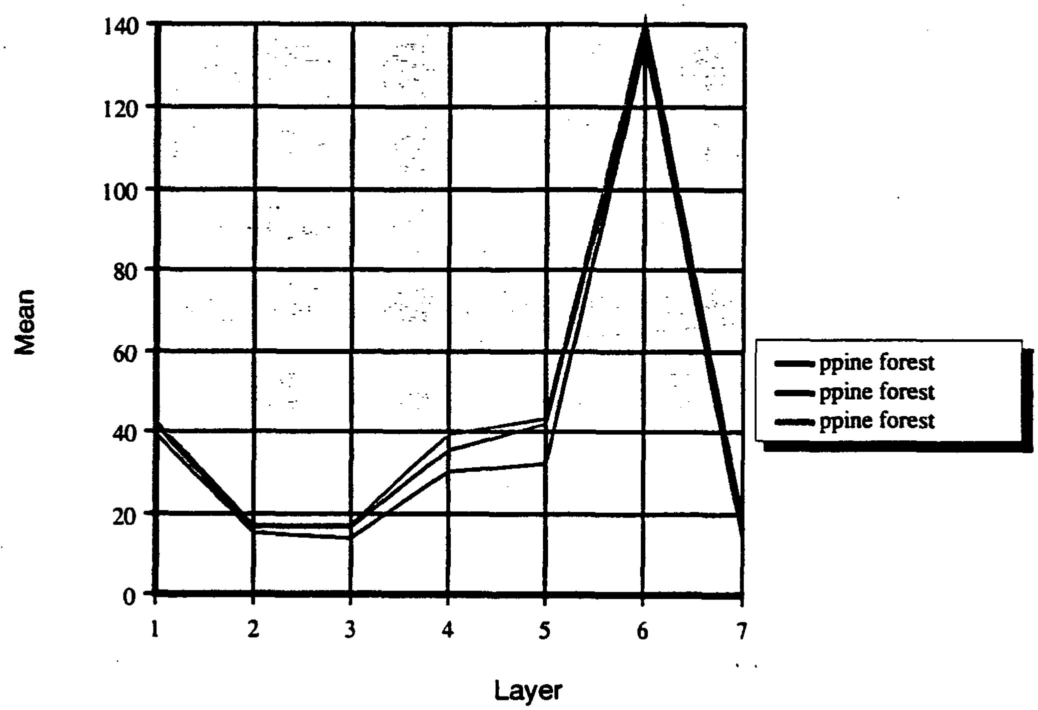


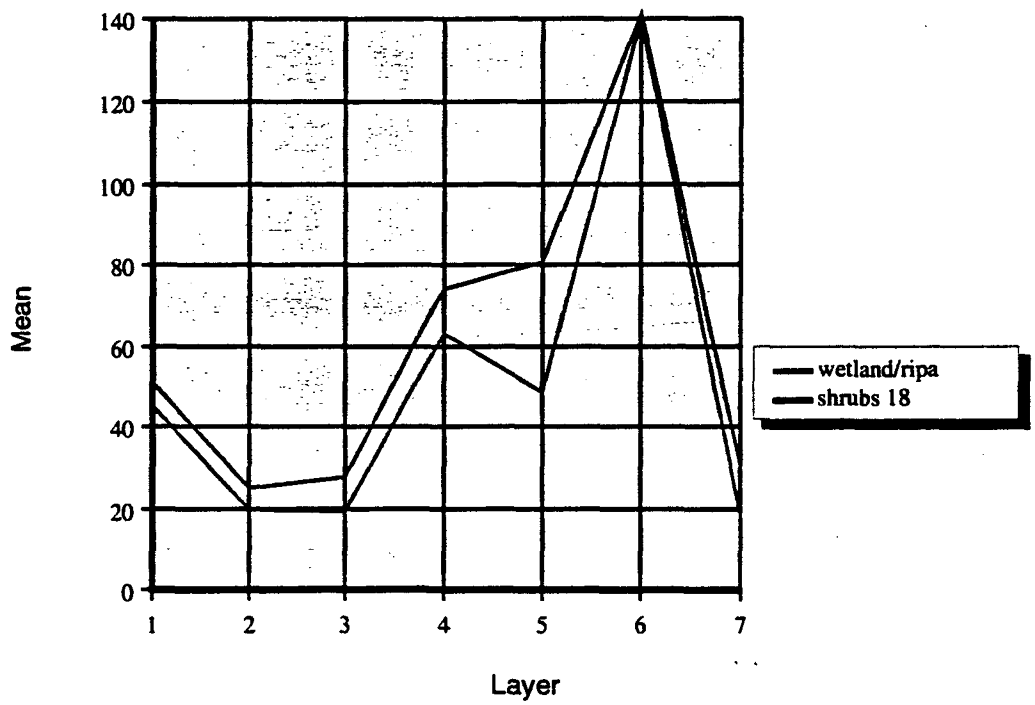
140
120
100
80
60
40
20
0
Mean
1
2
3
4
5
6
7
Layer
water 1
wetland/ripa


Mean
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
Layer
midgrass les
midgrass les
midgrass mor
midgrass mor

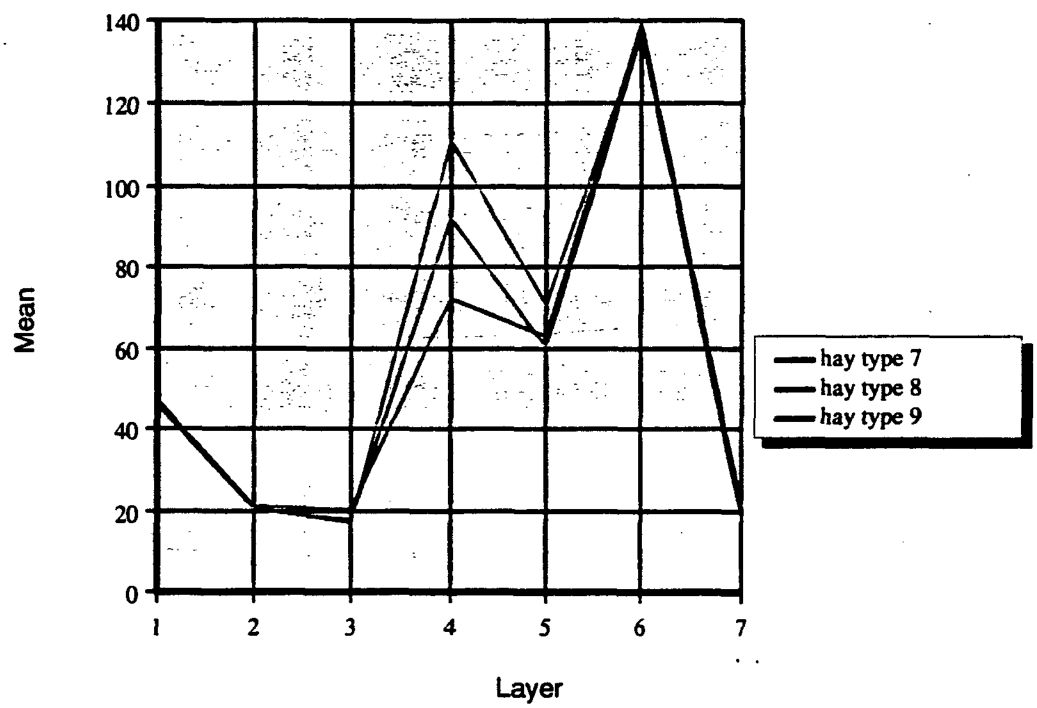


140
120
100
80
60
40
20
0
Mean
1
2
3
4
5
6
7
Layer
tallgrass 5
tallgrass 6


140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
Mean
Layer
ppine forest
ppine forest
ppine forest



140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
Mean
Layer
wetland/ripa
shrubs 18



140
120
100
80
60
40
20
0
Mean
1
2
3
4
5
6
7
Layer
hay type 7
hay type 8
hay type 9

Appendix 2. Data files used in analysis.

Bird species

| | |
|---|---|
| savannah | Savannah Sparrow |
| meadow | Western Meadowlark |
| bobolink | Bobolink |
| grasshop | Grasshopper Sparrow |
| hornedlark | Horned Lark |
| vesperspa | Vesper Sparrow |
| larksparro | Lark Sparrow |
| redwinged | Red-winged Blackbird |
| amrobin | American Robin |
| eurstarling | European Starling |
| cograckle | Common Grackle |
| housefinch | House Finch |
| housespar | House Sparrow |

| plot no. | savannah | meadow | bobolink | grasshop | homedlark | vesperspa | larksparro | redwinged |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.1 | 0 |
| 3 | 0 | 0.9 | 0 | 0 | 0 | 0.1 | 0.3 | 0 |
| 4 | 0 | 1.7 | 0 | 0.3 | 0 | 0.2 | 1.3 | 0 |
| 5 | 0 | 2.3 | 0 | 0.1 | 0 | 0.3 | 2 | 0 |
| 6 | 0 | 2.3 | 0 | 0.2 | 0 | 0.3 | 1.4 | 0 |
| 7 | 0 | 2.3 | 0 | 0.3 | 0 | 0 | 1.1 | 0 |
| 8 | 0 | 2.8 | 0 | 0 | 0 | 0.7 | 1.9 | 0 |
| 9 | 0 | 3 | 0 | 0.2 | 0 | 0.4 | 1.5 | 0 |
| 10 | 0 | 1.8 | 0 | 0 | 0 | 0 | 0.6 | 0 |
| 11 | 0 | 1.4 | 0 | 0 | 0 | 0 | 0.5 | 0 |
| 12 | 0 | 2 | 0 | 0.1 | 0 | 0 | 2.1 | 0 |
| 13 | 0 | 3.1 | 0 | 0.5 | 0 | 0.3 | 3.1 | 0 |
| 14 | 0 | 1.5 | 0 | 0 | 0 | 0 | 0.5 | 0.2 |
| 15 | 0 | 1.2 | 0 | 0 | 0 | 1.3 | 1 | 0 |
| 16 | 0 | 0.8 | 0 | 0 | 0.5 | 1.5 | 0 | 0 |
| 17 | 0 | 1.4 | 0 | 0.4 | 0.2 | 0.8 | 0 | 0 |
| 18 | 0 | 0.6 | 0 | 0.1 | 0 | 0.2 | 0 | 0 |
| 19 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 4.6 |
| 20 | 0.4 | 1.5 | 0 | 0 | 0 | 0.1 | 0 | 3.6 |
| 21 | 0.8 | 0.6 | 0.2 | 0 | 0 | 0.1 | 0 | 7.4 |
| 22 | 0 | 1 | 0 | 0 | 0 | 0.1 | 0 | 6.8 |
| 23 | 0 | 1.3 | 0 | 1.6 | 0 | 0.6 | 0 | 0 |
| 24 | 0 | 1.1 | 0 | 1.3 | 0 | 0.6 | 0 | 0 |
| 25 | 1 | 1 | 0.2 | 0 | 0 | 0 | 0 | 5.7 |
| 26 | 0.4 | 0.8 | 0.1 | 0 | 0 | 0 | 0 | 2.3 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.5 |
| 28 | 0 | 1.7 | 0 | 0.2 | 0 | 0 | 0 | 0 |
| 29 | 0 | 1.2 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| 30 | 0 | 1.5 | 0 | 0.1 | 0.2 | 0.1 | 0 | 0.1 |
| 31 | 0 | 1.8 | 0 | 0 | 0.2 | 0.2 | 0 | 0 |
| 32 | 0 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 4 |
| 33 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 4.4 |

| plot no. | savannah | meadow | bobolink | grasshop | homedlark | vesperspa | larksparro | redwinged |
|---|---|---|---|---|---|---|---|---|
| 34 | 0 | 0.2 | 1.1 | 0 | 0 | 0 | 0 | 2 |
| 35 | 0 | 0.3 | 1.5 | 0 | 0 | 0 | 0 | 2 |
| 36 | 0 | 0.3 | 0.9 | 0 | 0 | 0 | 0 | 4.2 |
| 37 | 0 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 2.5 |
| 38 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 2.2 |
| 39 | 0 | 0.9 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| 40 | 0 | 1.1 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| 41 | 0.6 | 0.3 | 3.1 | 0 | 0 | 0 | 0 | 4 |
| 42 | 0.6 | 0.1 | 3.4 | 0 | 0 | 0 | 0 | 4.9 |
| 43 | 1.4 | 1.6 | 0.5 | 0.7 | 0 | 0 | 0 | 1.9 |
| 44 | 0.9 | 1.5 | 0.2 | 1.4 | 0 | 0.1 | 0 | 3.3 |
| 45 | 0 | 1.4 | 0 | 1.5 | 0 | 0.1 | 0 | 0.4 |
| 46 | 0 | 1.4 | 0.1 | 0 | 0 | 0 | 0 | 1.7 |
| 47 | 0.1 | 1.3 | 0.2 | 0.1 | 0 | 0.1 | 0 | 1.2 |
| 48 | 0.1 | 1.9 | 0.3 | 0.2 | 0 | 0.1 | 0 | 1.7 |
| 49 | 0 | 0.8 | 0.4 | 0 | 0 | 0 | 0 | 5.5 |
| 50 | 0.1 | 1.2 | 0.7 | 0.3 | 0 | 0 | 0 | 0.9 |
| 51 | 0 | 0.9 | 0.9 | 0.5 | 0 | 0.1 | 0 | 2.3 |
| 52 | 0 | 1.9 | 0 | 0.4 | 0.7 | 2.4 | 0 | 0 |
| 53 | 0 | 2 | 0 | 0.5 | 0.9 | 1.6 | 0 | 0 |
| 54 | 0 | 2.3 | 0 | 0.2 | 0 | 0 | 0 | 0.6 |
| 55 | 0 | 1.5 | 0 | 0.2 | 0 | 1.5 | 0 | 0 |
| 56 | 0 | 1.3 | 0 | 0.1 | 0 | 0.7 | 0 | 1.4 |
| 57 | 0 | 1.2 | 0 | 0.8 | 0 | 0.7 | 0 | 0.7 |
| 58 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 59 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 0 | 1.3 | 0 | 0.7 | 2.7 | 1.8 | 0 | 0 |
| 61 | 0 | 1.2 | 0 | 0.3 | 1.3 | 2.4 | 0 | 0 |
| 62 | 0 | 2 | 0 | 0 | 2.4 | 1.8 | 0 | 0 |
| 63 | 0 | 1.6 | 0 | 0.3 | 0.2 | 2.3 | 0 | 0 |
| 64 | 0 | 1.8 | 0 | 0 | 0.1 | 1.8 | 0 | 0 |
| 65 | 0 | 1.6 | 0 | 0 | 0.8 | 1.1 | 0 | 0 |
| 66 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 |

| plot no. | amrobin | eurstarling | cograckle | housefinch | housespar |
|---|---|---|---|---|---|
| 1 | 0.1 | 1.8 | 1 | 0.5 | 1 |
| 2 | 0 | 2.7 | 1 | 0.5 | 0 |
| 3 | 0.4 | 2.9 | 0.9 | 0.5 | 0 |
| 4 | 0 | 0.6 | 0 | 0 | 0 |
| 5 | 0 | 1 | 0.1 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0.1 | 0 | 0 | 0 |
| 8 | 0 | 0.2 | 0 | 0.2 | 0 |
| 9 | 0 | 0.1 | 0 | 0.1 | 0 |
| 10 | 0 | 1.1 | 1.3 | 0.8 | 0 |
| 11 | 0.1 | 0.2 | 0.3 | 0.6 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0.3 | 1.2 | 0.6 | 0.7 | 0 |
| 15 | 0.2 | 1 | 1 | 0.7 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0.1 | 0 | 0 | 0 |
| 18 | 0.1 | 1.2 | 0 | 0.4 | 0.2 |
| 19 | 0 | 1.6 | 0.1 | 0 | 0 |
| 20 | 0.2 | 0.8 | 0.2 | 0 | 0 |
| 21 | 0.2 | 2.5 | 0.1 | 0 | 0 |
| 22 | 0 | 1.8 | 1.2 | 0.3 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0.3 | 2.3 | 0.9 | 0 | 0.2 |
| 26 | 0.4 | 1.9 | 0.3 | 0 | 0 |
| 27 | 0.4 | 1.7 | 0.5 | 0.5 | 0.7 |
| 28 | 0.3 | 0.8 | 0.8 | 0.8 | 0.6 |
| 29 | 0.2 | 0.6 | 0.4 | 0.7 | 1 |
| 30 | 0 | 0.5 | 0.3 | 1.1 | 0.2 |
| 31 | 0.4 | 0.4 | 0 | 0.2 | 0 |
| 32 | 1.3 | 3.1 | 3.4 | 1 | 0 |
| 33 | 0.8 | 1.4 | 2 | 2.2 | 0 |

| plot no. | amrobin | eurstarling | cograckle | housefinch | housespar |
|---|---|---|---|---|---|
| 34 | 0.4 | 3.8 | 2.5 | 0.6 | 0.2 |
| 35 | 0 | 2.7 | 2.7 | 1.9 | 0 |
| 36 | 0.2 | 1.3 | 1.2 | 0 | 0 |
| 37 | 0.7 | 5.9 | 1.5 | 0.2 | 0 |
| 38 | 0.3 | 6.1 | 3.2 | 0.7 | 0 |
| 39 | 1.9 | 0.8 | 1.6 | 0.6 | 0 |
| 40 | 2 | 1.8 | 0.9 | 0.9 | 0.5 |
| 41 | 0 | 0.3 | 0.1 | 0 | 0 |
| 42 | 0 | 0.2 | 0.1 | 0 | 0 |
| 43 | 0 | 0.3 | 0.1 | 0.3 | 0 |
| 44 | 0.2 | 0 | 0 | 0.5 | 0 |
| 45 | 1.1 | 2.9 | 0.8 | 0.2 | 0 |
| 46 | 0 | 0.4 | 0.1 | 0.4 | 0 |
| 47 | 0.1 | 0.3 | 0.8 | 0 | 0 |
| 48 | 0.7 | 0.3 | 2.3 | 0.2 | 0 |
| 49 | 0.6 | 2.5 | 1.6 | 0.2 | 0.3 |
| 50 | 0.1 | 0.9 | 0.9 | 0 | 0 |
| 51 | 0 | 4.5 | 0.7 | 0 | 0 |
| 52 | 0 | 0 | 0 | 0 | 0 |
| 53 | 0 | 0 | 0 | 0 | 0 |
| 54 | 0.2 | 0.8 | 0.3 | 0.1 | 0 |
| 55 | 0.4 | 0.1 | 0 | 0.3 | 0 |
| 56 | 0.1 | 0.2 | 0.1 | 0 | 0 |
| 57 | 0 | 0.1 | 0 | 0 | 0 |
| 58 | 0.8 | 1.2 | 1.5 | 1.3 | 0.1 |
| 59 | 0.3 | 0.9 | 1 | 0.5 | 0 |
| 60 | 0 | 0 | 0 | 0 | 0 |
| 61 | 0 | 0 | 0 | 0 | 0 |
| 62 | 0 | 0 | 0.1 | 0 | 0 |
| 63 | 0 | 0 | 0 | 0 | 0 |
| 64 | 0 | 0.1 | 0.1 | 0 | 0 |
| 65 | 0 | 0.7 | 0 | 0 | 0 |
| 66 | 1 | 1.6 | 2.3 | 0.1 | 0.2 |

Appendix 2. Continued.

State Plane Coordinates for sample plot locations.

| plot no. | x-coord | y-coord |
|---|---|---|
| 1 | 3057918 | 1262144 |
| 2 | 3058049 | 1262782 |
| 3 | 3058775 | 1265001 |
| 4 | 3059866 | 1268821 |
| 5 | 3059366 | 1269140 |
| 6 | 3063806 | 1271574 |
| 7 | 3064918 | 1271643 |
| 8 | 3063821 | 1272276 |
| 9 | 3064463 | 1272702 |
| 10 | 3066364 | 1271828 |
| 11 | 3066693 | 1271206 |
| 12 | 3061719 | 1277934 |
| 13 | 3062363 | 1277705 |
| 14 | 3065860 | 1275591 |
| 15 | 3065922 | 1275990 |
| 16 | 3070500 | 1272898 |
| 17 | 3070101 | 1273349 |
| 18 | 3071612 | 1278202 |
| 19 | 3077386 | 1278617 |
| 20 | 3077317 | 1278035 |
| 21 | 3075779 | 1275923 |
| 22 | 3077381 | 1275457 |
| 23 | 3098308 | 1266853 |
| 24 | 3098147 | 1266037 |
| 25 | 3074328 | 1263758 |
| 26 | 3074982 | 1263758 |
| 27 | 3072570 | 1257346 |
| 28 | 3070105 | 1229743 |
| 29 | 3069777 | 1229810 |
| 30 | 3081756 | 1259897 |
| 31 | 3080658 | 1259853 |
| 32 | 3091424 | 1245936 |
| 33 | 3092209 | 1245937 |

| plot no. | x-coord | y-coord |
|---|---|---|
| 34 | 3078549 | 1243461 |
| 35 | 3080265 | 1241925 |
| 36 | 3079741 | 1241127 |
| 37 | 3078758 | 1238378 |
| 38 | 3077638 | 1236684 |
| 39 | 3093787 | 1240763 |
| 40 | 3093833 | 1240212 |
| 41 | 3080801 | 1237289 |
| 42 | 3081036 | 1236415 |
| 43 | 3078967 | 1234559 |
| 44 | 3079691 | 1233598 |
| 45 | 3080068 | 1233118 |
| 46 | 3082655 | 1233974 |
| 47 | 3082899 | 1234026 |
| 48 | 3083492 | 1234185 |
| 49 | 3081036 | 1233121 |
| 50 | 3082483 | 1232281 |
| 51 | 3081473 | 1231978 |
| 52 | 3082703 | 1230293 |
| 53 | 3083473 | 1230524 |
| 54 | 3072738 | 1227408 |
| 55 | 3071697 | 1227491 |
| 56 | 3072179 | 1226463 |
| 57 | 3071703 | 1226467 |
| 58 | 3074464 | 1226978 |
| 59 | 3074393 | 1226613 |
| 60 | 3071956 | 1217577 |
| 61 | 3073111 | 1218263 |
| 62 | 3072979 | 1216674 |
| 63 | 3077453 | 1215445 |
| 64 | 3077986 | 1215826 |
| 65 | 3078193 | 1214038 |
| 66 | 3093289 | 1239999 |

Appendix 2. Continued. Habitat type categorical data for the 66 sample plots.

| plot no. | mixed grass | shortgrass | hayfield | tallgrass |
|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 |
| 4 | 1 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 |
| 6 | 0 | 1 | 0 | 0 |
| 7 | 0 | 1 | 0 | 0 |
| 8 | 0 | 1 | 0 | 0 |
| 9 | 0 | 1 | 0 | 0 |
| 10 | 0 | 1 | 0 | 0 |
| 11 | 0 | 1 | 0 | 0 |
| 12 | 1 | 0 | 0 | 0 |
| 13 | 1 | 0 | 0 | 0 |
| 14 | 0 | 1 | 0 | 0 |
| 15 | 0 | 1 | 0 | 0 |
| 16 | 0 | 1 | 0 | 0 |
| 17 | 0 | 1 | 0 | 0 |
| 19 | 0 | 0 | 1 | 0 |
| 20 | 0 | 0 | 1 | 0 |
| 21 | 0 | 0 | 1 | 0 |
| 22 | 0 | 0 | 1 | 0 |
| 23 | 1 | 0 | 0 | 0 |
| 24 | 1 | 0 | 0 | 0 |
| 25 | 0 | 0 | 1 | 0 |
| 26 | 0 | 0 | 1 | 0 |
| 28 | 1 | 0 | 0 | 0 |
| 29 | 1 | 0 | 0 | 0 |
| 30 | 0 | 1 | 0 | 0 |
| 31 | 0 | 1 | 0 | 0 |
| 32 | 0 | 0 | 1 | 0 |
| 33 | 0 | 0 | 1 | 0 |
| 34 | 0 | 0 | 1 | 0 |
| 35 | 0 | 0 | 1 | 0 |
| 36 | 0 | 0 | 0 | 1 |
| 37 | 0 | 0 | 1 | 0 |
| 38 | 0 | 0 | 1 | 0 |
| 39 | 0 | 0 | 1 | 0 |

| plot no. | mixed grass | shortgrass | hayfield | tallgrass |
|---|---|---|---|---|
| 40 | 0 | 0 | 1 | 0 |
| 41 | 0 | 0 | 1 | 0 |
| 42 | 0 | 0 | 1 | 0 |
| 43 | 0 | 0 | 0 | 1 |
| 44 | 0 | 0 | 0 | 1 |
| 45 | 0 | 0 | 0 | 1 |
| 46 | 0 | 0 | 0 | 1 |
| 47 | 0 | 0 | 0 | 1 |
| 48 | 0 | 0 | 0 | 1 |
| 49 | 0 | 0 | 1 | 0 |
| 50 | 0 | 0 | 1 | 0 |
| 51 | 0 | 0 | 1 | 0 |
| 52 | 1 | 0 | 0 | 0 |
| 53 | 1 | 0 | 0 | 0 |
| 54 | 0 | 0 | 0 | 1 |
| 55 | 1 | 0 | 0 | 0 |
| 56 | 0 | 0 | 0 | 1 |
| 57 | 1 | 0 | 0 | 0 |
| 58 | 0 | 0 | 0 | 1 |
| 59 | 0 | 0 | 0 | 1 |
| 60 | 1 | 0 | 0 | 0 |
| 61 | 1 | 0 | 0 | 0 |
| 62 | 0 | 1 | 0 | 0 |
| 63 | 0 | 1 | 0 | 0 |
| 64 | 0 | 1 | 0 | 0 |
| 65 | 0 | 1 | 0 | 0 |
| 66 | 1 | 0 | 0 | 0 |

Appendix 2. Continued.

Landscape data for Scale I.

(Key applies to all scales)

| | |
|---|---|
| water | percent water |
| conifer | percent conifer forest |
| savannah | percent Ponderosa pine/shrub savannah |
| midgrasslb | percent midgrass/mixed grass |
| wetland/riparian | percent wetland/riparian |
| midgrassmb | percent midgrass/shortgrass |
| hay/pasture | percent non-native hay/pasture |
| ponderosa pine | percent Ponderosa pine forest |
| shrubs | percent shrubs |
| bare soil | percent bare soil/rock |
| buildings/paved | percent buildings/paved |
| urban veg | percent urban vegetation |
| tallgrass/wet | percent native tallgrass (wetter) |
| tallgrass | percent tallgrass |
| area (ha) | area of the geometric sampling window |
| num patches | number of patches |
| dlfd | double log fractal dimension |
| contagion | percent contagion |
| perimeter/area | perimeter of all patches divided by area (ha) |
| tallgrass(total) | sum of tallgrass and tallgrass (wet) |
| urban(total) | sum of urban veg and buildings/paved |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 0.00 | 0.00 | 0.00 | 28.40 | 0.00 | 62.96 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.00 | 0.00 | 0.00 | 0.00 | 54.32 | 0.00 | 28.40 | 0.00 | 0.00 | 13.58 | 0.00 |
| 3.00 | 0.00 | 0.00 | 0.00 | 75.31 | 0.00 | 22.22 | 0.00 | 0.00 | 2.47 | 0.00 |
| 4.00 | 0.00 | 0.00 | 0.00 | 74.07 | 0.00 | 24.69 | 0.00 | 0.00 | 0.00 | 1.23 |
| 5.00 | 0.00 | 0.00 | 0.00 | 76.54 | 0.00 | 22.22 | 0.00 | 0.00 | 0.00 | 1.23 |
| 6.00 | 0.00 | 0.00 | 0.00 | 55.56 | 0.00 | 43.21 | 0.00 | 0.00 | 0.00 | 1.23 |
| 7.00 | 0.00 | 0.00 | 0.00 | 80.25 | 0.00 | 16.05 | 0.00 | 0.00 | 3.70 | 0.00 |
| 8.00 | 0.00 | 0.00 | 0.00 | 7.41 | 0.00 | 72.84 | 0.00 | 0.00 | 6.17 | 13.58 |
| 9.00 | 0.00 | 0.00 | 0.00 | 1.23 | 0.00 | 97.53 | 0.00 | 0.00 | 0.00 | 1.23 |
| 10.00 | 0.00 | 0.00 | 0.00 | 24.69 | 6.17 | 45.68 | 18.52 | 0.00 | 0.00 | 4.94 |
| 11.00 | 0.00 | 0.00 | 0.00 | 33.33 | 13.58 | 28.40 | 20.99 | 0.00 | 2.47 | 1.23 |
| 12.00 | 0.00 | 0.00 | 0.00 | 61.73 | 0.00 | 38.27 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13.00 | 0.00 | 0.00 | 0.00 | 62.96 | 0.00 | 29.63 | 0.00 | 0.00 | 7.41 | 0.00 |
| 14.00 | 0.00 | 0.00 | 0.00 | 64.20 | 8.64 | 19.75 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15.00 | 0.00 | 0.00 | 0.00 | 55.56 | 0.00 | 13.58 | 0.00 | 0.00 | 0.00 | 6.17 |
| 16.00 | 0.00 | 0.00 | 0.00 | 72.84 | 0.00 | 27.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17.00 | 0.00 | 0.00 | 0.00 | 72.84 | 0.00 | 12.35 | 14.81 | 0.00 | 0.00 | 0.00 |
| 18.00 | 0.00 | 0.00 | 0.00 | 38.27 | 0.00 | 34.57 | 18.52 | 0.00 | 0.00 | 0.00 |
| 19.00 | 0.00 | 0.00 | 0.00 | 6.17 | 0.00 | 0.00 | 93.83 | 0.00 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 8.64 | 0.00 | 0.00 | 91.36 | 0.00 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 14.81 | 0.00 | 7.41 | 77.78 | 0.00 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 3.70 | 4.94 | 2.47 | 88.89 | 0.00 | 0.00 | 0.00 |
| 23.00 | 0.00 | 0.00 | 0.00 | 40.74 | 0.00 | 59.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24.00 | 0.00 | 0.00 | 0.00 | 72.84 | 0.00 | 27.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 90.12 | 0.00 | 0.00 | 0.00 |
| 26.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.70 | 0.00 | 96.30 | 0.00 | 0.00 | 0.00 |
| 27.00 | 0.00 | 0.00 | 0.00 | 81.48 | 0.00 | 1.23 | 16.05 | 0.00 | 0.00 | 0.00 |
| 28.00 | 0.00 | 0.00 | 1.23 | 59.26 | 0.00 | 32.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 29.00 | 0.00 | 0.00 | 1.23 | 55.56 | 0.00 | 25.93 | 0.00 | 0.00 | 0.00 | 0.00 |
| 30.00 | 0.00 | 0.00 | 0.00 | 49.38 | 13.58 | 7.41 | 25.93 | 0.00 | 0.00 | 0.00 |
| 31.00 | 0.00 | 0.00 | 0.00 | 62.96 | 0.00 | 35.80 | 1.23 | 0.00 | 0.00 | 0.00 |
| 32.00 | 0.00 | 0.00 | 0.00 | 4.94 | 0.00 | 0.00 | 81.48 | 0.00 | 0.00 | 0.00 |
| 33.00 | 0.00 | 0.00 | 0.00 | 1.23 | 0.00 | 0.00 | 81.48 | 0.00 | 0.00 | 0.00 |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 0.00 | 0.00 | 0.00 | 1.23 | 0.00 | 0.00 | 7.41 | 0.00 | 0.00 | 0.00 |
| 35.00 | 0.00 | 0.00 | 0.00 | 11.11 | 12.35 | 1.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| 36.00 | 0.00 | 0.00 | 0.00 | 1.23 | 9.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 37.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 38.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.17 | 0.00 | 3.70 | 0.00 | 0.00 | 0.00 |
| 39.00 | 0.00 | 0.00 | 0.00 | 46.91 | 0.00 | 1.23 | 49.38 | 0.00 | 0.00 | 0.00 |
| 40.00 | 0.00 | 0.00 | 0.00 | 11.11 | 0.00 | 0.00 | 88.89 | 0.00 | 0.00 | 0.00 |
| 41.00 | 0.00 | 0.00 | 0.00 | 3.70 | 0.00 | 0.00 | 1.23 | 0.00 | 0.00 | 0.00 |
| 42.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 43.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 44.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 45.00 | 0.00 | 0.00 | 0.00 | 24.69 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 46.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48.00 | 0.00 | 0.00 | 0.00 | 6.17 | 13.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 49.00 | 0.00 | 0.00 | 0.00 | 2.47 | 1.23 | 0.00 | 2.47 | 0.00 | 0.00 | 0.00 |
| 50.00 | 0.00 | 0.00 | 0.00 | 27.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 51.00 | 0.00 | 0.00 | 0.00 | 37.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 52.00 | 0.00 | 0.00 | 0.00 | 82.72 | 0.00 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 |
| 53.00 | 0.00 | 0.00 | 0.00 | 97.53 | 0.00 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 |
| 54.00 | 0.00 | 0.00 | 0.00 | 24.69 | 14.81 | 4.94 | 7.41 | 0.00 | 0.00 | 0.00 |
| 55.00 | 0.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 56.00 | 0.00 | 0.00 | 0.00 | 20.99 | 3.70 | 0.00 | 1.23 | 0.00 | 0.00 | 0.00 |
| 57.00 | 0.00 | 0.00 | 0.00 | 53.09 | 7.41 | 1.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| 58.00 | 0.00 | 0.00 | 0.00 | 49.38 | 1.23 | 1.23 | 1.23 | 0.00 | 0.00 | 0.00 |
| 59.00 | 0.00 | 0.00 | 0.00 | 39.51 | 0.00 | 1.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| 60.00 | 0.00 | 0.00 | 1.23 | 98.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 61.00 | 0.00 | 0.00 | 0.00 | 87.65 | 0.00 | 12.35 | 0.00 | 0.00 | 0.00 | 0.00 |
| 62.00 | 0.00 | 0.00 | 4.94 | 30.86 | 0.00 | 64.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 63.00 | 0.00 | 0.00 | 0.00 | 25.93 | 0.00 | 74.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| 64.00 | 0.00 | 0.00 | 0.00 | 19.75 | 0.00 | 77.78 | 0.00 | 0.00 | 0.00 | 2.47 |
| 65.00 | 0.00 | 0.00 | 0.00 | 25.93 | 0.00 | 71.60 | 0.00 | 0.00 | 0.00 | 2.47 |
| 66.00 | 0.00 | 0.00 | 0.00 | 16.05 | 0.00 | 0.00 | 83.95 | 0.00 | 0.00 | 0.00 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 4.94 | 3.70 | 0.00 | 0.00 | 6.09 | 10.00 | 1.22 | 42.52 | 162.15 | 0.00 | 8.64 |
| 2.00 | 1.23 | 2.47 | 0.00 | 0.00 | 6.09 | 7.00 | 1.40 | 40.52 | 220.71 | 0.00 | 3.70 |
| 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 7.00 | 1.20 | 49.35 | 121.61 | 0.00 | 0.00 |
| 4.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 6.00 | 1.19 | 50.96 | 112.61 | 0.00 | 0.00 |
| 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.35 | 50.04 | 135.12 | 0.00 | 0.00 |
| 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.26 | 44.15 | 117.11 | 0.00 | 0.00 |
| 7.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.15 | 54.19 | 90.08 | 0.00 | 0.00 |
| 8.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 7.00 | 1.17 | 47.87 | 157.64 | 0.00 | 0.00 |
| 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.01 | 90.30 | 18.01 | 0.00 | 0.00 |
| 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 11.00 | 1.44 | 28.31 | 261.23 | 0.00 | 0.00 |
| 11.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 14.00 | 1.42 | 31.14 | 292.78 | 0.00 | 0.00 |
| 12.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 6.00 | 1.35 | 8.52 | 198.18 | 0.00 | 0.00 |
| 13.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 7.00 | 1.43 | 28.29 | 198.18 | 0.00 | 0.00 |
| 14.00 | 3.70 | 3.70 | 0.00 | 0.00 | 6.09 | 10.00 | 1.25 | 44.67 | 175.67 | 0.00 | 7.40 |
| 15.00 | 13.58 | 11.11 | 0.00 | 0.00 | 6.09 | 13.00 | 1.30 | 32.84 | 229.70 | 0.00 | 24.69 |
| 16.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 5.00 | 1.38 | 20.43 | 162.15 | 0.00 | 0.00 |
| 17.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 6.00 | 1.28 | 37.44 | 148.64 | 0.00 | 0.00 |
| 18.00 | 6.17 | 2.47 | 0.00 | 0.00 | 6.09 | 8.00 | 1.27 | 34.24 | 184.66 | 0.00 | 8.64 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 2.00 | 0.77 | 70.48 | 40.54 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.12 | 60.17 | 67.57 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.16 | 50.34 | 94.58 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 7.00 | 1.18 | 68.96 | 99.10 | 0.00 | 0.00 |
| 23.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 7.00 | 1.36 | 6.26 | 211.69 | 0.00 | 0.00 |
| 24.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 6.00 | 1.30 | 20.80 | 157.64 | 0.00 | 0.00 |
| 25.00 | 0.00 | 9.88 | 0.00 | 0.00 | 6.09 | 2.00 | 1.04 | 60.59 | 49.54 | 0.00 | 9.88 |
| 26.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.08 | 76.97 | 49.54 | 0.00 | 0.00 |
| 27.00 | 1.23 | 0.00 | 0.00 | 0.00 | 6.09 | 6.00 | 1.14 | 65.66 | 85.58 | 0.00 | 1.23 |
| 28.00 | 0.00 | 7.41 | 0.00 | 0.00 | 6.09 | 8.00 | 1.24 | 44.09 | 157.64 | 0.00 | 7.41 |
| 29.00 | 1.23 | 16.05 | 0.00 | 0.00 | 6.09 | 8.00 | 1.33 | 41.65 | 202.68 | 0.00 | 17.28 |
| 30.00 | 3.70 | 0.00 | 0.00 | 0.00 | 6.09 | 11.00 | 1.43 | 28.68 | 265.75 | 0.00 | 3.70 |
| 31.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 5.00 | 1.47 | 39.89 | 189.18 | 0.00 | 0.00 |
| 32.00 | 0.00 | 13.58 | 0.00 | 0.00 | 6.09 | 5.00 | 1.16 | 52.84 | 103.60 | 0.00 | 13.58 |
| 33.00 | 0.00 | 17.28 | 0.00 | 0.00 | 6.09 | 3.00 | 1.14 | 61.33 | 67.57 | 0.00 | 17.28 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 4.94 | 0.00 | 4.94 | 81.48 | 6.09 | 12.00 | 1.21 | 61.11 | 148.64 | 86.42 | 4.94 |
| 35.00 | 0.00 | 1.23 | 70.37 | 3.70 | 6.09 | 10.00 | 1.33 | 52.47 | 189.18 | 74.07 | 1.23 |
| 36.00 | 0.00 | 0.00 | 65.43 | 23.46 | 6.09 | 7.00 | 1.37 | 41.17 | 198.18 | 88.89 | 0.00 |
| 37.00 | 0.00 | 0.00 | 14.81 | 71.60 | 6.09 | 13.00 | 1.35 | 30.75 | 216.19 | 86.41 | 0.00 |
| 38.00 | 0.00 | 0.00 | 18.52 | 71.60 | 6.09 | 5.00 | 1.36 | 46.50 | 157.64 | 90.12 | 0.00 |
| 39.00 | 0.00 | 2.47 | 0.00 | 0.00 | 6.09 | 6.00 | 1.20 | 51.88 | 117.11 | 0.00 | 2.47 |
| 40.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.10 | 55.84 | 63.05 | 0.00 | 0.00 |
| 41.00 | 0.00 | 1.23 | 1.23 | 92.59 | 6.09 | 6.00 | 1.02 | 81.94 | 49.54 | 93.82 | 1.23 |
| 42.00 | 0.00 | 0.00 | 0.00 | 97.53 | 6.09 | 2.00 | 1.03 | 84.30 | 22.51 | 97.53 | 0.00 |
| 43.00 | 0.00 | 0.00 | 83.95 | 7.41 | 6.09 | 6.00 | 1.24 | 53.39 | 121.61 | 91.36 | 0.00 |
| 44.00 | 0.00 | 0.00 | 13.58 | 74.07 | 6.09 | 10.00 | 1.21 | 39.66 | 144.14 | 87.65 | 0.00 |
| 45.00 | 0.00 | 3.70 | 20.99 | 48.15 | 6.09 | 13.00 | 1.30 | 31.35 | 243.22 | 69.14 | 3.70 |
| 46.00 | 0.00 | 0.00 | 28.40 | 59.26 | 6.09 | 9.00 | 1.20 | 25.12 | 184.66 | 87.66 | 0.00 |
| 47.00 | 0.00 | 0.00 | 32.10 | 54.32 | 6.09 | 6.00 | 1.40 | 21.21 | 198.18 | 86.42 | 0.00 |
| 48.00 | 0.00 | 0.00 | 32.10 | 48.15 | 6.09 | 11.00 | 1.38 | 23.58 | 261.23 | 80.25 | 0.00 |
| 49.00 | 0.00 | 27.16 | 3.70 | 62.96 | 6.09 | 7.00 | 1.24 | 54.25 | 144.14 | 66.66 | 27.16 |
| 50.00 | 0.00 | 0.00 | 7.41 | 65.43 | 6.09 | 8.00 | 1.45 | 28.82 | 211.69 | 72.84 | 0.00 |
| 51.00 | 0.00 | 0.00 | 1.23 | 61.73 | 6.09 | 3.00 | 1.34 | 42.79 | 139.62 | 62.96 | 0.00 |
| 52.00 | 0.00 | 0.00 | 0.00 | 14.81 | 6.09 | 3.00 | 1.10 | 61.06 | 67.57 | 14.81 | 0.00 |
| 53.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.05 | 84.40 | 27.03 | 0.00 | 0.00 |
| 54.00 | 0.00 | 0.00 | 3.70 | 44.44 | 6.09 | 13.00 | 1.33 | 30.81 | 261.23 | 48.14 | 0.00 |
| 55.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 56.00 | 0.00 | 0.00 | 24.69 | 49.38 | 6.09 | 10.00 | 1.39 | 32.53 | 261.23 | 74.07 | 0.00 |
| 57.00 | 0.00 | 0.00 | 13.58 | 24.69 | 6.09 | 9.00 | 1.22 | 37.03 | 189.18 | 38.27 | 0.00 |
| 58.00 | 0.00 | 13.58 | 25.93 | 7.41 | 6.09 | 13.00 | 1.43 | 39.20 | 279.26 | 33.34 | 13.58 |
| 59.00 | 0.00 | 0.00 | 46.91 | 12.35 | 6.09 | 10.00 | 1.50 | 29.53 | 283.76 | 59.26 | 0.00 |
| 60.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 2.00 | 1.00 | 92.23 | 9.01 | 0.00 | 0.00 |
| 61.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.12 | 51.30 | 76.57 | 0.00 | 0.00 |
| 62.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 5.00 | 1.48 | 36.33 | 175.67 | 0.00 | 0.00 |
| 63.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 3.00 | 1.16 | 26.82 | 117.11 | 0.00 | 0.00 |
| 64.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.36 | 46.94 | 166.65 | 0.00 | 0.00 |
| 65.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.28 | 46.67 | 121.61 | 0.00 | 0.00 |
| 66.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.09 | 4.00 | 1.33 | 38.35 | 126.11 | 0.00 | 0.00 |

Appendix 2. Continued.

Landscape data for Scale II.

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 3.40 | 0.76 | 0.19 | 28.73 | 1.51 | 49.34 | 0.00 | 0.38 | 1.70 | 0.00 |
| 2.00 | 0.00 | 0.00 | 0.19 | 34.97 | 0.00 | 50.66 | 0.00 | 0.00 | 2.84 | 0.00 |
| 3.00 | 0.00 | 0.00 | 0.95 | 38.37 | 0.00 | 45.18 | 0.00 | 0.00 | 1.13 | 0.95 |
| 4.00 | 0.00 | 0.00 | 0.00 | 60.68 | 1.13 | 23.63 | 0.00 | 0.00 | 0.76 | 7.18 |
| 5.00 | 0.00 | 0.00 | 0.00 | 57.28 | 2.08 | 34.78 | 0.00 | 0.00 | 1.13 | 1.89 |
| 6.00 | 0.00 | 0.00 | 0.00 | 32.89 | 0.00 | 55.39 | 0.00 | 0.00 | 4.35 | 7.37 |
| 7.00 | 0.00 | 0.00 | 0.00 | 39.13 | 0.00 | 49.91 | 0.00 | 0.00 | 2.27 | 8.70 |
| 8.00 | 0.00 | 0.00 | 0.00 | 27.03 | 0.00 | 56.52 | 0.00 | 0.00 | 8.51 | 7.94 |
| 9.00 | 0.00 | 0.00 | 0.00 | 15.12 | 0.00 | 69.75 | 0.00 | 0.00 | 8.70 | 6.43 |
| 10.00 | 0.00 | 0.00 | 0.00 | 24.76 | 3.59 | 32.89 | 27.60 | 0.00 | 0.38 | 10.78 |
| 11.00 | 0.00 | 0.00 | 0.00 | 24.95 | 4.73 | 29.11 | 32.70 | 0.00 | 1.32 | 7.18 |
| 12.00 | 0.00 | 0.00 | 0.00 | 58.79 | 0.00 | 29.30 | 0.00 | 0.00 | 7.18 | 4.73 |
| 13.00 | 0.00 | 0.00 | 0.00 | 66.73 | 0.00 | 25.33 | 0.00 | 0.00 | 6.43 | 1.51 |
| 14.00 | 2.27 | 0.00 | 0.00 | 38.94 | 8.13 | 22.87 | 0.19 | 0.00 | 0.00 | 2.46 |
| 15.00 | 3.02 | 0.00 | 0.00 | 39.32 | 8.32 | 16.26 | 0.38 | 0.00 | 0.00 | 2.08 |
| 16.00 | 0.00 | 0.00 | 0.00 | 44.23 | 0.57 | 22.68 | 31.38 | 0.00 | 0.00 | 1.13 |
| 17.00 | 0.00 | 0.00 | 0.00 | 44.99 | 0.19 | 17.01 | 37.62 | 0.00 | 0.00 | 0.00 |
| 18.00 | 0.00 | 0.00 | 0.00 | 14.37 | 0.00 | 28.73 | 24.57 | 0.00 | 0.00 | 9.45 |
| 19.00 | 0.00 | 0.00 | 0.00 | 34.59 | 1.13 | 5.10 | 58.98 | 0.00 | 0.00 | 0.19 |
| 20.00 | 0.00 | 0.00 | 0.00 | 21.36 | 3.02 | 1.70 | 73.91 | 0.00 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 13.23 | 0.76 | 9.45 | 76.56 | 0.00 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 13.99 | 1.13 | 11.72 | 72.78 | 0.00 | 0.00 | 0.38 |
| 23.00 | 0.00 | 0.00 | 0.00 | 58.03 | 0.00 | 31.00 | 0.00 | 0.00 | 0.00 | 10.96 |
| 24.00 | 0.00 | 0.00 | 0.00 | 70.70 | 0.00 | 26.09 | 0.00 | 0.00 | 0.00 | 3.02 |
| 25.00 | 0.00 | 0.00 | 0.00 | 6.05 | 3.40 | 1.32 | 85.44 | 0.00 | 0.00 | 0.95 |
| 26.00 | 0.00 | 0.00 | 0.00 | 8.51 | 5.86 | 1.32 | 80.34 | 0.00 | 0.00 | 0.95 |
| 27.00 | 10.02 | 0.00 | 0.00 | 32.89 | 6.81 | 4.73 | 25.14 | 0.00 | 0.00 | 3.59 |
| 28.00 | 0.00 | 0.38 | 4.16 | 41.02 | 0.00 | 30.62 | 0.00 | 0.00 | 0.76 | 0.00 |
| 29.00 | 0.00 | 0.19 | 3.59 | 37.24 | 0.00 | 28.73 | 0.00 | 0.00 | 0.57 | 0.00 |
| 30.00 | 0.00 | 0.00 | 0.00 | 26.09 | 7.18 | 10.21 | 55.01 | 0.00 | 0.00 | 0.19 |
| 31.00 | 0.00 | 0.00 | 0.00 | 47.26 | 5.10 | 14.56 | 32.89 | 0.00 | 0.00 | 0.19 |
| 32.00 | 0.00 | 0.00 | 0.00 | 6.24 | 1.13 | 5.29 | 57.28 | 0.00 | 0.00 | 0.00 |
| 33.00 | 0.00 | 0.00 | 0.00 | 8.13 | 0.00 | 10.96 | 51.04 | 0.00 | 0.00 | 0.19 |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 0.00 | 0.00 | 0.00 | 7.18 | 8.70 | 0.57 | 8.70 | 0.00 | 0.00 | 0.00 |
| 35.00 | 7.94 | 0.00 | 0.00 | 18.53 | 19.85 | 3.40 | 0.38 | 0.00 | 0.00 | 0.76 |
| 36.00 | 3.02 | 0.00 | 0.00 | 9.07 | 19.85 | 0.76 | 0.19 | 0.00 | 0.00 | 0.57 |
| 37.00 | 0.00 | 0.00 | 0.00 | 3.97 | 11.72 | 2.84 | 1.13 | 0.00 | 0.00 | 0.00 |
| 38.00 | 0.00 | 0.00 | 0.00 | 4.73 | 11.34 | 0.19 | 0.95 | 0.00 | 0.00 | 0.00 |
| 39.00 | 0.00 | 0.00 | 0.00 | 25.14 | 0.00 | 3.78 | 42.72 | 0.00 | 0.00 | 6.81 |
| 40.00 | 0.00 | 0.00 | 0.00 | 31.00 | 0.00 | 2.84 | 49.34 | 0.00 | 0.00 | 4.16 |
| 41.00 | 0.00 | 0.00 | 0.00 | 14.56 | 6.99 | 3.40 | 6.81 | 0.00 | 0.00 | 0.19 |
| 42.00 | 0.00 | 0.00 | 0.00 | 4.35 | 9.07 | 0.57 | 2.84 | 0.00 | 0.00 | 0.00 |
| 43.00 | 0.00 | 0.00 | 0.00 | 4.16 | 8.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 44.00 | 0.00 | 0.00 | 0.00 | 15.50 | 12.10 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 |
| 45.00 | 0.00 | 0.00 | 0.00 | 16.64 | 9.64 | 0.38 | 0.57 | 0.00 | 0.00 | 0.00 |
| 46.00 | 0.00 | 0.00 | 0.00 | 5.48 | 17.39 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 |
| 47.00 | 0.19 | 0.00 | 0.00 | 5.67 | 18.53 | 0.19 | 1.13 | 0.00 | 0.00 | 0.00 |
| 48.00 | 0.19 | 0.00 | 0.00 | 11.72 | 18.53 | 2.65 | 0.95 | 0.00 | 0.00 | 0.38 |
| 49.00 | 0.00 | 0.00 | 0.00 | 17.77 | 8.51 | 0.57 | 1.13 | 0.00 | 0.00 | 0.00 |
| 50.00 | 0.00 | 0.00 | 0.00 | 20.42 | 7.94 | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 |
| 51.00 | 0.00 | 0.00 | 0.00 | 17.58 | 2.27 | 0.19 | 2.65 | 0.00 | 0.00 | 0.00 |
| 52.00 | 0.00 | 0.00 | 0.19 | 45.37 | 0.00 | 22.87 | 0.00 | 0.00 | 0.00 | 0.00 |
| 53.00 | 0.00 | 0.00 | 3.78 | 56.71 | 0.00 | 24.57 | 0.00 | 0.00 | 0.00 | 0.00 |
| 54.00 | 0.00 | 0.00 | 0.00 | 34.40 | 11.53 | 1.32 | 3.78 | 0.00 | 0.00 | 0.38 |
| 55.00 | 0.00 | 0.00 | 0.38 | 77.88 | 0.38 | 0.19 | 2.08 | 0.00 | 0.00 | 0.00 |
| 56.00 | 0.00 | 0.00 | 0.00 | 40.45 | 15.12 | 2.08 | 3.02 | 0.00 | 0.00 | 0.00 |
| 57.00 | 0.00 | 0.00 | 0.00 | 60.11 | 7.18 | 0.19 | 2.27 | 0.00 | 0.00 | 0.00 |
| 58.00 | 0.00 | 0.00 | 0.00 | 30.43 | 13.42 | 3.21 | 3.02 | 0.00 | 0.00 | 0.95 |
| 59.00 | 0.00 | 0.00 | 0.00 | 35.16 | 10.02 | 4.35 | 1.32 | 0.00 | 0.00 | 1.32 |
| 60.00 | 0.00 | 3.21 | 14.56 | 75.99 | 0.38 | 5.67 | 0.00 | 0.19 | 0.00 | 0.00 |
| 61.00 | 0.00 | 5.10 | 6.99 | 63.89 | 0.00 | 20.60 | 0.00 | 0.00 | 0.00 | 0.00 |
| 62.00 | 0.00 | 0.00 | 7.94 | 60.87 | 0.00 | 31.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| 63.00 | 0.00 | 0.00 | 0.57 | 30.06 | 0.00 | 65.03 | 0.00 | 0.00 | 1.51 | 2.08 |
| 64.00 | 0.00 | 0.00 | 0.00 | 15.50 | 1.32 | 77.69 | 0.00 | 0.00 | 2.27 | 2.46 |
| 65.00 | 0.00 | 0.00 | 0.19 | 33.46 | 0.19 | 58.03 | 0.00 | 0.00 | 5.29 | 1.13 |
| 66.00 | 0.00 | 0.00 | 0.00 | 14.56 | 0.00 | 0.38 | 66.35 | 0.00 | 0.00 | 0.57 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 4.54 | 9.45 | 0.00 | 0.00 | 39.80 | 34.00 | 1.47 | 51.86 | 210.89 | 0.00 | 13.99 |
| 2.00 | 4.54 | 6.81 | 0.00 | 0.00 | 39.80 | 29.00 | 1.47 | 46.46 | 194.35 | 0.00 | 11.35 |
| 3.00 | 13.42 | 0.00 | 0.00 | 0.00 | 39.80 | 30.00 | 1.41 | 47.95 | 177.81 | 0.00 | 13.42 |
| 4.00 | 6.62 | 0.00 | 0.00 | 0.00 | 39.80 | 26.00 | 1.36 | 49.15 | 164.72 | 0.00 | 6.62 |
| 5.00 | 2.84 | 0.00 | 0.00 | 0.00 | 39.80 | 22.00 | 1.38 | 53.99 | 150.24 | 0.00 | 2.84 |
| 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 18.00 | 1.35 | 40.57 | 144.73 | 0.00 | 0.00 |
| 7.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 29.00 | 1.42 | 37.48 | 179.88 | 0.00 | 0.00 |
| 8.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 22.00 | 1.35 | 36.41 | 161.96 | 0.00 | 0.00 |
| 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 29.00 | 1.35 | 44.66 | 151.62 | 0.00 | 0.00 |
| 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 51.00 | 1.47 | 31.10 | 259.83 | 0.00 | 0.00 |
| 11.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 37.00 | 1.46 | 35.08 | 225.37 | 0.00 | 0.00 |
| 12.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 28.00 | 1.50 | 34.90 | 213.65 | 0.00 | 0.00 |
| 13.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 29.00 | 1.42 | 44.26 | 184.02 | 0.00 | 0.00 |
| 14.00 | 11.53 | 13.61 | 0.00 | 0.00 | 39.80 | 42.00 | 1.43 | 37.55 | 233.64 | 0.00 | 25.14 |
| 15.00 | 11.15 | 19.47 | 0.00 | 0.00 | 39.80 | 43.00 | 1.43 | 38.46 | 226.06 | 0.00 | 30.62 |
| 16.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 18.00 | 1.46 | 42.01 | 186.08 | 0.00 | 0.00 |
| 17.00 | 0.00 | 0.19 | 0.00 | 0.00 | 39.80 | 20.00 | 1.33 | 48.33 | 147.49 | 0.00 | 0.19 |
| 18.00 | 13.04 | 9.83 | 0.00 | 0.00 | 39.80 | 27.00 | 1.40 | 29.56 | 206.07 | 0.00 | 22.87 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 21.00 | 1.38 | 54.04 | 139.22 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 23.00 | 1.37 | 55.05 | 123.37 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 21.00 | 1.41 | 54.98 | 132.33 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 21.00 | 1.43 | 57.10 | 136.46 | 0.00 | 0.00 |
| 23.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 12.00 | 1.49 | 30.96 | 168.16 | 0.00 | 0.00 |
| 24.00 | 0.19 | 0.00 | 0.00 | 0.00 | 39.80 | 16.00 | 1.40 | 55.24 | 146.11 | 0.00 | 0.19 |
| 25.00 | 0.00 | 2.84 | 0.00 | 0.00 | 39.80 | 23.00 | 1.27 | 71.24 | 90.28 | 0.00 | 2.84 |
| 26.00 | 0.00 | 3.02 | 0.00 | 0.00 | 39.80 | 27.00 | 1.36 | 63.89 | 125.43 | 0.00 | 3.02 |
| 27.00 | 11.72 | 5.10 | 0.00 | 0.00 | 39.80 | 43.00 | 1.41 | 34.15 | 218.47 | 0.00 | 16.82 |
| 28.00 | 2.84 | 19.28 | 0.19 | 0.76 | 39.80 | 27.00 | 1.41 | 51.25 | 187.46 | 0.95 | 22.12 |
| 29.00 | 6.05 | 23.63 | 0.00 | 0.00 | 39.80 | 26.00 | 1.40 | 44.90 | 185.39 | 0.00 | 29.68 |
| 30.00 | 1.13 | 0.19 | 0.00 | 0.00 | 39.80 | 33.00 | 1.45 | 48.11 | 208.14 | 0.00 | 1.32 |
| 31.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 20.00 | 1.39 | 43.47 | 158.52 | 0.00 | 0.00 |
| 32.00 | 0.19 | 29.87 | 0.00 | 0.00 | 39.80 | 16.00 | 1.29 | 56.84 | 97.87 | 0.00 | 30.06 |
| 33.00 | 0.19 | 29.49 | 0.00 | 0.00 | 39.80 | 13.00 | 1.29 | 54.28 | 98.56 | 0.00 | 29.68 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 5.67 | 16.64 | 9.64 | 42.91 | 39.80 | 60.00 | 1.40 | 35.33 | 241.91 | 52.55 | 22.31 |
| 35.00 | 0.19 | 0.38 | 37.43 | 11.15 | 39.80 | 48.00 | 1.42 | 42.48 | 247.42 | 48.58 | 0.57 |
| 36.00 | 0.19 | 1.13 | 47.07 | 18.15 | 39.80 | 41.00 | 1.42 | 48.17 | 223.30 | 65.22 | 1.32 |
| 37.00 | 5.29 | 12.48 | 21.55 | 41.02 | 39.80 | 69.00 | 1.43 | 32.46 | 274.30 | 62.57 | 17.77 |
| 38.00 | 0.95 | 1.89 | 17.96 | 62.00 | 39.80 | 52.00 | 1.49 | 48.79 | 245.35 | 79.96 | 2.84 |
| 39.00 | 1.51 | 20.04 | 0.00 | 0.00 | 39.80 | 30.00 | 1.32 | 40.29 | 160.58 | 0.00 | 21.55 |
| 40.00 | 1.32 | 11.34 | 0.00 | 0.00 | 39.80 | 27.00 | 1.36 | 45.39 | 158.52 | 0.00 | 12.66 |
| 41.00 | 4.91 | 1.13 | 6.62 | 55.39 | 39.80 | 56.00 | 1.39 | 45.04 | 206.76 | 62.01 | 6.04 |
| 42.00 | 0.00 | 0.38 | 7.75 | 75.05 | 39.80 | 32.00 | 1.37 | 60.02 | 146.80 | 82.80 | 0.38 |
| 43.00 | 1.13 | 1.51 | 45.94 | 38.56 | 39.80 | 39.00 | 1.34 | 46.69 | 161.27 | 84.50 | 2.64 |
| 44.00 | 0.57 | 4.91 | 22.31 | 44.23 | 39.80 | 50.00 | 1.38 | 38.68 | 216.41 | 66.54 | 5.48 |
| 45.00 | 0.38 | 6.99 | 16.45 | 48.96 | 39.80 | 58.00 | 1.40 | 41.25 | 246.04 | 65.41 | 7.37 |
| 46.00 | 0.95 | 2.27 | 14.74 | 58.22 | 39.80 | 55.00 | 1.47 | 43.10 | 246.04 | 72.96 | 3.22 |
| 47.00 | 0.76 | 1.89 | 16.64 | 55.01 | 39.80 | 64.00 | 1.47 | 46.95 | 263.27 | 71.65 | 2.65 |
| 48.00 | 0.00 | 1.70 | 22.87 | 41.02 | 39.80 | 62.00 | 1.47 | 39.53 | 291.53 | 63.89 | 1.70 |
| 49.00 | 1.32 | 8.32 | 15.69 | 46.69 | 39.80 | 67.00 | 1.40 | 36.63 | 268.10 | 62.38 | 9.64 |
| 50.00 | 0.57 | 1.89 | 8.13 | 60.49 | 39.80 | 46.00 | 1.47 | 46.63 | 225.37 | 68.62 | 2.46 |
| 51.00 | 0.00 | 2.46 | 9.83 | 65.03 | 39.80 | 36.00 | 1.43 | 50.71 | 195.73 | 74.86 | 2.46 |
| 52.00 | 0.00 | 0.00 | 0.57 | 31.00 | 39.80 | 10.00 | 1.33 | 50.67 | 107.52 | 31.57 | 0.00 |
| 53.00 | 0.00 | 0.00 | 0.00 | 14.93 | 39.80 | 11.00 | 1.29 | 43.25 | 106.14 | 14.93 | 0.00 |
| 54.00 | 0.57 | 0.00 | 13.23 | 34.78 | 39.80 | 55.00 | 1.46 | 39.05 | 259.14 | 48.01 | 0.57 |
| 55.00 | 0.00 | 0.00 | 4.54 | 14.56 | 39.80 | 33.00 | 1.31 | 68.13 | 114.41 | 19.10 | 0.00 |
| 56.00 | 0.00 | 0.00 | 11.91 | 27.41 | 39.80 | 52.00 | 1.42 | 32.88 | 229.50 | 39.32 | 0.00 |
| 57.00 | 0.00 | 0.00 | 7.37 | 22.87 | 39.80 | 37.00 | 1.34 | 49.37 | 157.14 | 30.24 | 0.00 |
| 58.00 | 9.07 | 6.24 | 19.85 | 13.80 | 39.80 | 76.00 | 1.50 | 28.09 | 319.10 | 33.65 | 15.31 |
| 59.00 | 11.91 | 5.48 | 18.90 | 11.53 | 39.80 | 67.00 | 1.50 | 31.00 | 300.49 | 30.43 | 17.39 |
| 60.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 14.00 | 1.31 | 67.32 | 82.70 | 0.00 | 0.00 |
| 61.00 | 3.40 | 0.00 | 0.00 | 0.00 | 39.80 | 18.00 | 1.36 | 49.06 | 133.02 | 0.00 | 3.40 |
| 62.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.80 | 9.00 | 1.42 | 36.17 | 139.22 | 0.00 | 0.00 |
| 63.00 | 0.76 | 0.00 | 0.00 | 0.00 | 39.80 | 23.00 | 1.39 | 59.63 | 146.80 | 0.00 | 0.76 |
| 64.00 | 0.76 | 0.00 | 0.00 | 0.00 | 39.80 | 32.00 | 1.42 | 61.43 | 160.58 | 0.00 | 0.76 |
| 65.00 | 1.70 | 0.00 | 0.00 | 0.00 | 39.80 | 22.00 | 1.37 | 58.14 | 158.52 | 0.00 | 1.70 |
| 66.00 | 0.76 | 17.39 | 0.00 | 0.00 | 39.80 | 23.00 | 1.34 | 57.90 | 133.02 | 0.00 | 18.15 |

Appendix 2. Continued.

Landscape data for Scale III.

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 6.06 | 0.29 | 0.22 | 30.31 | 2.70 | 45.14 | 0.15 | 0.15 | 1.83 | 0.15 |
| 2.00 | 2.48 | 0.29 | 0.07 | 28.34 | 1.17 | 52.23 | 0.00 | 0.15 | 1.31 | 0.00 |
| 3.00 | 0.00 | 0.37 | 0.58 | 27.61 | 0.00 | 47.04 | 0.00 | 0.00 | 1.46 | 1.46 |
| 4.00 | 0.00 | 0.00 | 0.00 | 47.63 | 2.48 | 37.98 | 0.00 | 0.00 | 0.66 | 5.92 |
| 5.00 | 0.00 | 0.00 | 0.00 | 46.38 | 3.58 | 40.76 | 0.00 | 0.00 | 0.44 | 4.89 |
| 6.00 | 0.51 | 0.00 | 0.00 | 30.75 | 1.17 | 57.93 | 0.00 | 0.00 | 5.11 | 4.53 |
| 7.00 | 0.15 | 0.00 | 0.00 | 32.07 | 1.39 | 54.35 | 1.39 | 0.00 | 3.58 | 7.09 |
| 8.00 | 0.00 | 0.00 | 0.00 | 26.59 | 0.00 | 61.50 | 0.00 | 0.00 | 6.57 | 5.33 |
| 9.00 | 0.00 | 0.00 | 0.00 | 24.54 | 0.00 | 61.72 | 0.07 | 0.00 | 5.55 | 8.11 |
| 10.00 | 0.00 | 0.00 | 0.00 | 25.79 | 2.41 | 33.82 | 29.00 | 0.00 | 0.88 | 8.11 |
| 11.00 | 2.34 | 0.00 | 0.00 | 23.45 | 5.41 | 29.80 | 32.29 | 0.00 | 1.17 | 5.55 |
| 12.00 | 0.00 | 0.00 | 1.31 | 54.49 | 0.00 | 31.34 | 0.00 | 0.00 | 4.60 | 8.25 |
| 13.00 | 0.00 | 0.00 | 0.15 | 60.34 | 0.00 | 30.97 | 0.00 | 0.00 | 5.11 | 3.43 |
| 14.00 | 3.58 | 0.00 | 0.00 | 33.09 | 5.70 | 26.52 | 3.58 | 0.00 | 0.88 | 1.97 |
| 15.00 | 5.48 | 0.00 | 0.00 | 31.19 | 6.36 | 22.72 | 0.95 | 0.00 | 0.66 | 1.31 |
| 16.00 | 1.10 | 0.00 | 0.00 | 29.88 | 5.77 | 10.74 | 50.99 | 0.00 | 0.00 | 0.44 |
| 17.00 | 0.07 | 0.00 | 0.00 | 34.04 | 2.19 | 11.61 | 44.49 | 0.00 | 0.00 | 0.44 |
| 18.00 | 0.00 | 0.00 | 0.00 | 17.24 | 0.66 | 23.08 | 29.44 | 0.00 | 0.00 | 6.06 |
| 19.00 | 0.00 | 0.00 | 0.00 | 32.36 | 3.87 | 9.86 | 52.81 | 0.00 | 0.00 | 1.10 |
| 20.00 | 0.00 | 0.00 | 0.00 | 25.86 | 3.36 | 6.06 | 64.35 | 0.00 | 0.00 | 0.37 |
| 21.00 | 0.00 | 0.00 | 0.00 | 19.80 | 2.56 | 11.47 | 64.57 | 0.00 | 0.00 | 1.61 |
| 22.00 | 6.87 | 0.00 | 0.00 | 12.64 | 4.16 | 8.11 | 67.79 | 0.00 | 0.00 | 0.44 |
| 23.00 | 0.00 | 0.00 | 0.00 | 56.32 | 0.00 | 23.67 | 0.22 | 0.00 | 0.00 | 19.72 |
| 24.00 | 0.00 | 0.00 | 0.00 | 64.79 | 0.00 | 25.57 | 0.29 | 0.00 | 0.00 | 9.28 |
| 25.00 | 0.00 | 0.00 | 0.00 | 10.88 | 3.73 | 2.34 | 80.72 | 0.00 | 0.00 | 0.73 |
| 26.00 | 0.00 | 0.00 | 0.00 | 13.29 | 4.67 | 2.63 | 76.70 | 0.00 | 0.00 | 0.95 |
| 27.00 | 13.15 | 0.00 | 0.00 | 23.37 | 6.72 | 8.77 | 20.96 | 0.00 | 0.00 | 3.21 |
| 28.00 | 0.00 | 0.15 | 3.21 | 43.32 | 0.22 | 25.71 | 0.22 | 0.07 | 0.37 | 0.07 |
| 29.00 | 0.00 | 0.15 | 3.36 | 41.49 | 0.00 | 25.13 | 0.22 | 0.07 | 0.29 | 0.00 |
| 30.00 | 0.66 | 0.00 | 0.00 | 22.06 | 10.88 | 7.60 | 57.63 | 0.00 | 0.00 | 0.66 |
| 31.00 | 0.22 | 0.00 | 0.00 | 30.83 | 12.34 | 7.52 | 47.92 | 0.00 | 0.00 | 0.66 |
| 32.00 | 0.00 | 0.00 | 0.00 | 13.15 | 4.31 | 7.60 | 46.68 | 0.00 | 0.00 | 1.24 |
| 33.00 | 0.00 | 0.00 | 0.00 | 11.54 | 1.24 | 9.79 | 48.14 | 0.00 | 0.00 | 2.56 |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 0.00 | 0.00 | 0.00 | 4.60 | 13.59 | 0.29 | 9.72 | 0.00 | 0.00 | 0.07 |
| 35.00 | 19.72 | 0.00 | 0.00 | 10.96 | 16.44 | 2.78 | 2.85 | 0.00 | 0.00 | 0.73 |
| 36.00 | 14.24 | 0.00 | 0.00 | 13.95 | 13.81 | 2.19 | 3.80 | 0.00 | 0.00 | 0.29 |
| 37.00 | 0.73 | 0.00 | 0.00 | 10.74 | 10.74 | 3.14 | 3.80 | 0.00 | 0.00 | 0.00 |
| 38.00 | 0.00 | 0.00 | 0.00 | 9.72 | 8.91 | 2.85 | 2.05 | 0.00 | 0.00 | 0.00 |
| 39.00 | 0.00 | 0.00 | 0.00 | 21.40 | 0.07 | 3.94 | 42.59 | 0.00 | 0.00 | 2.70 |
| 40.00 | 0.00 | 0.00 | 0.00 | 23.37 | 0.07 | 4.82 | 39.37 | 0.00 | 0.00 | 2.70 |
| 41.00 | 0.00 | 0.00 | 0.00 | 10.45 | 12.13 | 1.97 | 5.19 | 0.00 | 0.00 | 0.07 |
| 42.00 | 0.00 | 0.00 | 0.00 | 10.59 | 8.77 | 2.92 | 5.33 | 0.00 | 0.00 | 0.07 |
| 43.00 | 0.00 | 0.00 | 0.00 | 5.70 | 15.78 | 0.22 | 0.22 | 0.00 | 0.00 | 0.00 |
| 44.00 | 0.00 | 0.00 | 0.00 | 14.76 | 9.13 | 1.10 | 0.29 | 0.00 | 0.00 | 0.00 |
| 45.00 | 0.00 | 0.00 | 0.00 | 17.46 | 8.84 | 1.10 | 1.10 | 0.00 | 0.00 | 0.00 |
| 46.00 | 0.07 | 0.00 | 0.00 | 16.65 | 14.02 | 2.63 | 1.24 | 0.00 | 0.00 | 0.07 |
| 47.00 | 0.07 | 0.00 | 0.00 | 16.58 | 14.32 | 2.19 | 1.24 | 0.00 | 0.00 | 0.15 |
| 48.00 | 0.07 | 0.00 | 0.00 | 17.31 | 15.34 | 1.61 | 1.90 | 0.00 | 0.00 | 0.15 |
| 49.00 | 0.00 | 0.00 | 0.00 | 18.70 | 8.47 | 1.10 | 1.31 | 0.00 | 0.00 | 0.00 |
| 50.00 | 0.00 | 0.00 | 0.37 | 20.75 | 7.96 | 0.07 | 0.66 | 0.00 | 0.00 | 0.00 |
| 51.00 | 0.00 | 0.00 | 0.07 | 20.60 | 3.80 | 0.37 | 1.97 | 0.00 | 0.00 | 0.00 |
| 52.00 | 0.00 | 0.00 | 0.88 | 34.84 | 0.07 | 28.34 | 0.07 | 0.00 | 0.00 | 0.00 |
| 53.00 | 0.00 | 0.29 | 4.89 | 39.81 | 0.58 | 32.07 | 0.07 | 0.00 | 0.00 | 0.37 |
| 54.00 | 0.29 | 0.00 | 0.00 | 44.63 | 10.45 | 3.65 | 5.04 | 0.00 | 0.00 | 0.51 |
| 55.00 | 0.00 | 0.07 | 5.84 | 58.44 | 6.28 | 1.68 | 4.31 | 0.00 | 0.07 | 0.15 |
| 56.00 | 0.00 | 0.15 | 1.02 | 52.74 | 8.77 | 6.36 | 2.92 | 0.00 | 0.00 | 0.29 |
| 57.00 | 0.00 | 0.00 | 3.80 | 58.66 | 7.09 | 5.55 | 2.41 | 0.00 | 0.00 | 0.00 |
| 58.00 | 0.00 | 0.00 | 0.15 | 29.00 | 12.34 | 11.61 | 3.07 | 0.00 | 0.00 | 1.24 |
| 59.00 | 0.00 | 0.00 | 0.51 | 31.41 | 11.54 | 13.15 | 3.29 | 0.00 | 0.00 | 1.10 |
| 60.00 | 0.00 | 4.09 | 18.41 | 63.40 | 0.29 | 13.66 | 0.00 | 0.15 | 0.00 | 0.00 |
| 61.00 | 0.00 | 5.77 | 13.00 | 58.29 | 0.44 | 19.43 | 0.00 | 0.00 | 0.00 | 0.00 |
| 62.00 | 0.00 | 0.22 | 7.38 | 67.86 | 0.00 | 22.35 | 0.00 | 0.00 | 0.00 | 0.07 |
| 63.00 | 0.00 | 1.68 | 4.16 | 33.75 | 1.17 | 54.05 | 0.00 | 0.15 | 1.68 | 1.53 |
| 64.00 | 0.00 | 0.07 | 1.46 | 35.65 | 1.83 | 53.83 | 0.00 | 0.00 | 4.09 | 1.75 |
| 65.00 | 0.00 | 0.22 | 0.51 | 43.97 | 1.31 | 43.90 | 0.00 | 0.00 | 7.82 | 1.24 |
| 66.00 | 0.00 | 0.00 | 0.00 | 18.63 | 0.00 | 2.92 | 40.03 | 0.00 | 0.00 | 2.85 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 2.12 | 10.88 | 0.00 | 0.00 | 103.00 | 61.00 | 1.42 | 55.68 | 177.63 | 0.00 | 13.00 |
| 2.00 | 2.12 | 11.83 | 0.00 | 0.00 | 103.00 | 53.00 | 1.44 | 57.71 | 162.45 | 0.00 | 13.95 |
| 3.00 | 19.80 | 1.68 | 0.00 | 0.00 | 103.00 | 65.00 | 1.42 | 51.52 | 168.31 | 0.00 | 21.48 |
| 4.00 | 5.33 | 0.00 | 0.00 | 0.00 | 103.00 | 61.00 | 1.43 | 45.43 | 185.09 | 0.00 | 5.33 |
| 5.00 | 3.94 | 0.00 | 0.00 | 0.00 | 103.00 | 49.00 | 1.44 | 48.38 | 159.25 | 0.00 | 3.94 |
| 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 43.00 | 1.39 | 52.50 | 153.40 | 0.00 | 0.00 |
| 7.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 67.00 | 1.48 | 50.55 | 194.14 | 0.00 | 0.00 |
| 8.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 44.00 | 1.38 | 42.51 | 142.21 | 0.00 | 0.00 |
| 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 57.00 | 1.42 | 47.91 | 161.65 | 0.00 | 0.00 |
| 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 78.00 | 1.49 | 36.20 | 213.58 | 0.00 | 0.00 |
| 11.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 82.00 | 1.47 | 38.89 | 209.59 | 0.00 | 0.00 |
| 12.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 61.00 | 1.51 | 40.21 | 216.51 | 0.00 | 0.00 |
| 13.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 50.00 | 1.52 | 47.33 | 201.86 | 0.00 | 0.00 |
| 14.00 | 9.93 | 14.76 | 0.00 | 0.00 | 103.00 | 82.00 | 1.45 | 39.36 | 215.98 | 0.00 | 24.69 |
| 15.00 | 11.83 | 19.50 | 0.00 | 0.00 | 103.00 | 84.00 | 1.45 | 39.64 | 217.58 | 0.00 | 31.33 |
| 16.00 | 0.00 | 1.10 | 0.00 | 0.00 | 103.00 | 48.00 | 1.41 | 50.07 | 168.04 | 0.00 | 1.10 |
| 17.00 | 1.53 | 5.62 | 0.00 | 0.00 | 103.00 | 62.00 | 1.46 | 48.70 | 196.54 | 0.00 | 7.15 |
| 18.00 | 9.42 | 14.10 | 0.00 | 0.00 | 103.00 | 63.00 | 1.45 | 34.72 | 200.80 | 0.00 | 23.52 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 77.00 | 1.44 | 42.05 | 181.89 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 52.00 | 1.41 | 52.35 | 136.35 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 70.00 | 1.48 | 47.10 | 177.90 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 59.00 | 1.44 | 53.20 | 144.61 | 0.00 | 0.00 |
| 23.00 | 0.07 | 0.00 | 0.00 | 0.00 | 103.00 | 34.00 | 1.46 | 51.47 | 144.34 | 0.00 | 0.07 |
| 24.00 | 0.07 | 0.00 | 0.00 | 0.00 | 103.00 | 27.00 | 1.42 | 56.85 | 130.23 | 0.00 | 0.07 |
| 25.00 | 0.37 | 1.24 | 0.00 | 0.00 | 103.00 | 52.00 | 1.38 | 68.63 | 110.52 | 0.00 | 1.61 |
| 26.00 | 0.37 | 1.39 | 0.00 | 0.00 | 103.00 | 60.00 | 1.44 | 63.50 | 137.42 | 0.00 | 1.76 |
| 27.00 | 15.49 | 8.33 | 0.00 | 0.00 | 103.00 | 130.00 | 1.46 | 26.70 | 256.72 | 0.00 | 23.82 |
| 28.00 | 4.82 | 19.07 | 0.51 | 2.26 | 103.00 | 64.00 | 1.45 | 56.95 | 183.75 | 2.77 | 23.89 |
| 29.00 | 5.26 | 22.43 | 0.22 | 1.39 | 103.00 | 57.00 | 1.47 | 54.47 | 187.48 | 1.61 | 27.69 |
| 30.00 | 0.44 | 0.07 | 0.00 | 0.00 | 103.00 | 70.00 | 1.47 | 52.31 | 194.41 | 0.00 | 0.51 |
| 31.00 | 0.44 | 0.07 | 0.00 | 0.00 | 103.00 | 66.00 | 1.45 | 51.52 | 190.68 | 0.00 | 0.51 |
| 32.00 | 0.44 | 26.59 | 0.00 | 0.00 | 103.00 | 64.00 | 1.39 | 46.81 | 152.86 | 0.00 | 27.03 |
| 33.00 | 0.44 | 26.30 | 0.00 | 0.00 | 103.00 | 50.00 | 1.36 | 49.99 | 127.56 | 0.00 | 26.74 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 6.36 | 20.82 | 11.40 | 33.16 | 103.00 | 123.00 | 1.48 | 35.80 | 251.13 | 44.56 | 27.18 |
| 35.00 | 0.29 | 1.10 | 23.67 | 21.48 | 103.00 | 122.00 | 1.46 | 38.34 | 234.62 | 45.15 | 1.39 |
| 36.00 | 1.83 | 3.29 | 29.07 | 17.53 | 103.00 | 106.00 | 1.40 | 37.61 | 217.04 | 46.60 | 5.12 |
| 37.00 | 4.89 | 14.32 | 22.13 | 29.51 | 103.00 | 149.00 | 1.44 | 30.34 | 264.98 | 51.64 | 19.21 |
| 38.00 | 6.43 | 7.16 | 15.92 | 46.97 | 103.00 | 165.00 | 1.47 | 32.37 | 276.43 | 62.89 | 13.59 |
| 39.00 | 2.34 | 26.95 | 0.00 | 0.00 | 103.00 | 59.00 | 1.29 | 48.45 | 129.69 | 0.00 | 29.29 |
| 40.00 | 2.48 | 27.17 | 0.00 | 0.00 | 103.00 | 72.00 | 1.34 | 44.27 | 160.59 | 0.00 | 29.65 |
| 41.00 | 3.14 | 0.73 | 16.36 | 49.96 | 103.00 | 129.00 | 1.44 | 42.95 | 229.03 | 66.32 | 3.87 |
| 42.00 | 3.29 | 1.10 | 11.18 | 56.76 | 103.00 | 127.00 | 1.44 | 45.21 | 219.71 | 67.94 | 4.39 |
| 43.00 | 1.02 | 2.41 | 28.41 | 46.24 | 103.00 | 123.00 | 1.46 | 45.01 | 227.96 | 74.65 | 3.43 |
| 44.00 | 1.10 | 3.73 | 26.00 | 43.90 | 103.00 | 111.00 | 1.40 | 41.98 | 217.84 | 69.90 | 4.83 |
| 45.00 | 0.95 | 3.43 | 17.97 | 49.16 | 103.00 | 118.00 | 1.40 | 42.14 | 220.24 | 67.13 | 4.38 |
| 46.00 | 1.31 | 2.12 | 14.46 | 47.41 | 103.00 | 142.00 | 1.47 | 43.01 | 268.71 | 61.87 | 3.43 |
| 47.00 | 1.24 | 2.41 | 15.34 | 46.46 | 103.00 | 141.00 | 1.46 | 42.59 | 268.17 | 61.80 | 3.65 |
| 48.00 | 0.80 | 4.02 | 21.69 | 37.11 | 103.00 | 141.00 | 1.49 | 39.28 | 279.63 | 58.80 | 4.82 |
| 49.00 | 1.17 | 3.87 | 14.32 | 51.06 | 103.00 | 127.00 | 1.42 | 40.94 | 238.08 | 65.38 | 5.04 |
| 50.00 | 1.24 | 2.34 | 8.40 | 58.22 | 103.00 | 110.00 | 1.46 | 50.89 | 207.19 | 66.62 | 3.58 |
| 51.00 | 0.51 | 3.36 | 9.72 | 59.61 | 103.00 | 119.00 | 1.41 | 51.35 | 210.39 | 69.33 | 3.87 |
| 52.00 | 0.29 | 0.00 | 1.10 | 34.40 | 103.00 | 32.00 | 1.35 | 58.93 | 104.39 | 35.50 | 0.29 |
| 53.00 | 0.80 | 0.00 | 0.22 | 20.89 | 103.00 | 36.00 | 1.36 | 58.62 | 119.84 | 21.11 | 0.80 |
| 54.00 | 1.83 | 0.07 | 11.03 | 22.50 | 103.00 | 128.00 | 1.47 | 43.17 | 241.81 | 33.53 | 1.90 |
| 55.00 | 0.00 | 0.00 | 6.28 | 16.87 | 103.00 | 100.00 | 1.44 | 53.39 | 181.62 | 23.15 | 0.00 |
| 56.00 | 0.29 | 0.00 | 7.16 | 20.31 | 103.00 | 109.00 | 1.46 | 49.03 | 211.18 | 27.47 | 0.29 |
| 57.00 | 0.22 | 0.00 | 5.99 | 16.29 | 103.00 | 102.00 | 1.45 | 47.38 | 193.08 | 22.28 | 0.22 |
| 58.00 | 7.60 | 2.41 | 14.54 | 18.04 | 103.00 | 171.00 | 1.47 | 30.56 | 303.59 | 32.58 | 10.01 |
| 59.00 | 6.28 | 2.41 | 13.59 | 16.73 | 103.00 | 159.00 | 1.46 | 31.47 | 289.21 | 30.32 | 8.69 |
| 60.00 | 0.00 | 0.00 | 0.00 | 0.00 | 103.00 | 40.00 | 1.41 | 55.44 | 134.22 | 0.00 | 0.00 |
| 61.00 | 3.07 | 0.00 | 0.00 | 0.00 | 103.00 | 43.00 | 1.44 | 47.54 | 162.98 | 0.00 | 3.07 |
| 62.00 | 2.12 | 0.00 | 0.00 | 0.00 | 103.00 | 36.00 | 1.47 | 58.61 | 147.80 | 0.00 | 2.12 |
| 63.00 | 1.83 | 0.00 | 0.00 | 0.00 | 103.00 | 67.00 | 1.51 | 55.21 | 193.61 | 0.00 | 1.83 |
| 64.00 | 1.31 | 0.00 | 0.00 | 0.00 | 103.00 | 62.00 | 1.44 | 56.31 | 166.44 | 0.00 | 1.31 |
| 65.00 | 1.02 | 0.00 | 0.00 | 0.00 | 103.00 | 59.00 | 1.42 | 55.62 | 177.36 | 0.00 | 1.02 |
| 66.00 | 3.14 | 32.43 | 0.00 | 0.00 | 103.00 | 78.00 | 1.38 | 40.71 | 164.85 | 0.00 | 35.57 |

Appendix 2. Continued.

Landscape data for Scale IV.

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 2.59 | 4.22 | 1.23 | 24.16 | 2.22 | 39.46 | 0.37 | 1.48 | 1.32 | 1.32 |
| 2.00 | 2.59 | 3.82 | 0.62 | 25.98 | 2.06 | 41.58 | 0.37 | 1.60 | 1.23 | 1.26 |
| 3.00 | 0.00 | 1.05 | 0.92 | 21.45 | 0.52 | 46.78 | 0.00 | 0.68 | 1.35 | 1.20 |
| 4.00 | 0.00 | 0.00 | 0.00 | 39.12 | 1.97 | 48.17 | 0.00 | 0.00 | 1.05 | 4.22 |
| 5.00 | 0.00 | 0.00 | 0.00 | 35.73 | 1.97 | 53.34 | 0.00 | 0.00 | 1.05 | 3.97 |
| 6.00 | 0.98 | 0.00 | 0.00 | 34.04 | 1.66 | 52.91 | 0.15 | 0.00 | 4.65 | 5.26 |
| 7.00 | 0.98 | 0.00 | 0.00 | 30.87 | 2.34 | 49.25 | 7.57 | 0.00 | 3.14 | 5.85 |
| 8.00 | 0.68 | 0.00 | 0.00 | 31.49 | 1.23 | 55.83 | 0.15 | 0.00 | 4.68 | 5.54 |
| 9.00 | 0.03 | 0.00 | 0.00 | 27.89 | 1.51 | 55.40 | 4.37 | 0.00 | 3.63 | 5.85 |
| 10.00 | 1.20 | 0.00 | 0.00 | 28.16 | 4.49 | 32.19 | 26.72 | 0.00 | 2.31 | 4.92 |
| 11.00 | 1.17 | 0.00 | 0.00 | 34.35 | 4.52 | 27.09 | 27.24 | 0.00 | 1.57 | 4.06 |
| 12.00 | 0.22 | 0.06 | 1.17 | 50.97 | 0.95 | 30.75 | 5.02 | 0.00 | 3.51 | 7.29 |
| 13.00 | 1.54 | 0.03 | 0.80 | 54.97 | 1.60 | 28.47 | 3.63 | 0.00 | 3.39 | 5.48 |
| 14.00 | 5.17 | 0.00 | 0.00 | 29.27 | 4.43 | 25.85 | 4.92 | 0.00 | 2.19 | 2.12 |
| 15.00 | 7.36 | 0.00 | 0.00 | 29.02 | 5.05 | 22.65 | 3.85 | 0.00 | 1.75 | 1.48 |
| 16.00 | 0.58 | 0.00 | 0.00 | 28.84 | 5.05 | 5.82 | 50.97 | 0.00 | 0.00 | 0.31 |
| 17.00 | 0.77 | 0.00 | 0.00 | 23.58 | 4.99 | 6.09 | 48.48 | 0.00 | 0.00 | 0.49 |
| 18.00 | 0.74 | 0.00 | 0.00 | 20.96 | 1.91 | 15.24 | 33.98 | 0.00 | 0.00 | 4.49 |
| 19.00 | 0.00 | 0.00 | 0.00 | 22.01 | 5.69 | 11.67 | 59.31 | 0.00 | 0.00 | 1.32 |
| 20.00 | 0.00 | 0.00 | 0.00 | 21.02 | 4.12 | 10.83 | 62.57 | 0.00 | 0.00 | 1.45 |
| 21.00 | 5.20 | 0.00 | 0.00 | 20.59 | 4.03 | 11.88 | 55.31 | 0.00 | 0.00 | 2.99 |
| 22.00 | 18.50 | 0.00 | 0.00 | 16.31 | 3.82 | 8.56 | 51.92 | 0.00 | 0.00 | 0.89 |
| 23.00 | 0.00 | 0.00 | 0.00 | 49.83 | 0.03 | 20.78 | 0.71 | 0.00 | 0.00 | 28.62 |
| 24.00 | 0.00 | 0.00 | 0.00 | 59.31 | 0.03 | 23.30 | 0.58 | 0.00 | 0.00 | 16.74 |
| 25.00 | 0.00 | 0.00 | 0.00 | 12.62 | 4.86 | 4.46 | 74.42 | 0.00 | 0.00 | 1.60 |
| 26.00 | 0.86 | 0.00 | 0.00 | 13.67 | 5.76 | 4.12 | 71.68 | 0.00 | 0.00 | 1.51 |
| 27.00 | 5.60 | 0.00 | 0.00 | 18.87 | 4.40 | 8.99 | 22.65 | 0.00 | 0.00 | 5.42 |
| 28.00 | 0.00 | 0.22 | 3.08 | 41.58 | 0.40 | 20.87 | 2.15 | 0.03 | 0.34 | 0.22 |
| 29.00 | 0.00 | 0.12 | 3.76 | 41.77 | 0.31 | 21.79 | 1.11 | 0.03 | 0.37 | 0.22 |
| 30.00 | 4.68 | 0.00 | 0.00 | 17.48 | 12.47 | 6.19 | 57.25 | 0.00 | 0.00 | 1.54 |
| 31.00 | 0.77 | 0.00 | 0.00 | 18.84 | 10.59 | 6.62 | 60.51 | 0.00 | 0.00 | 2.12 |
| 32.00 | 0.12 | 0.00 | 0.00 | 12.80 | 4.65 | 7.54 | 53.43 | 0.00 | 0.00 | 1.69 |
| 33.00 | 0.12 | 0.00 | 0.00 | 12.96 | 4.25 | 8.34 | 52.48 | 0.00 | 0.00 | 2.09 |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 0.86 | 0.00 | 0.00 | 5.29 | 11.14 | 0.95 | 8.77 | 0.00 | 0.00 | 0.25 |
| 35.00 | 27.15 | 0.00 | 0.00 | 9.17 | 10.34 | 2.77 | 6.53 | 0.00 | 0.00 | 0.46 |
| 36.00 | 18.65 | 0.00 | 0.00 | 9.60 | 11.79 | 2.52 | 8.65 | 0.00 | 0.00 | 0.40 |
| 37.00 | 4.31 | 0.00 | 0.00 | 9.48 | 10.13 | 2.62 | 4.46 | 0.00 | 0.00 | 0.09 |
| 38.00 | 0.22 | 0.00 | 0.15 | 11.17 | 8.40 | 5.36 | 2.55 | 0.00 | 0.00 | 2.09 |
| 39.00 | 1.11 | 0.00 | 0.00 | 15.94 | 0.83 | 4.92 | 37.15 | 0.00 | 0.00 | 1.45 |
| 40.00 | 1.39 | 0.00 | 0.00 | 19.94 | 0.58 | 4.59 | 33.52 | 0.00 | 0.00 | 1.42 |
| 41.00 | 2.74 | 0.00 | 0.00 | 11.79 | 13.27 | 2.03 | 3.23 | 0.00 | 0.00 | 0.06 |
| 42.00 | 0.37 | 0.00 | 0.00 | 13.05 | 12.37 | 2.43 | 3.54 | 0.00 | 0.00 | 0.06 |
| 43.00 | 0.00 | 0.00 | 0.00 | 10.74 | 10.96 | 2.89 | 2.46 | 0.00 | 0.00 | 0.83 |
| 44.00 | 0.00 | 0.00 | 0.00 | 13.08 | 10.16 | 1.05 | 1.08 | 0.00 | 0.00 | 0.00 |
| 45.00 | 0.00 | 0.00 | 0.00 | 16.37 | 8.46 | 1.08 | 1.29 | 0.00 | 0.00 | 0.00 |
| 46.00 | 0.03 | 0.09 | 1.20 | 22.04 | 10.65 | 1.60 | 2.95 | 0.00 | 0.00 | 0.06 |
| 47.00 | 0.03 | 0.09 | 1.02 | 22.44 | 9.91 | 1.60 | 3.97 | 0.00 | 0.00 | 0.06 |
| 48.00 | 0.03 | 0.06 | 0.58 | 26.72 | 9.08 | 2.77 | 7.51 | 0.00 | 0.00 | 0.31 |
| 49.00 | 0.03 | 0.00 | 0.03 | 17.85 | 9.23 | 1.08 | 1.45 | 0.00 | 0.00 | 0.00 |
| 50.00 | 0.00 | 0.12 | 1.75 | 28.53 | 7.57 | 4.34 | 1.02 | 0.00 | 0.00 | 0.06 |
| 51.00 | 0.00 | 0.00 | 0.22 | 28.04 | 7.05 | 5.08 | 0.95 | 0.00 | 0.00 | 0.00 |
| 52.00 | 0.00 | 0.95 | 7.39 | 32.16 | 2.12 | 22.84 | 0.80 | 0.28 | 0.12 | 0.22 |
| 53.00 | 0.00 | 2.12 | 8.40 | 34.66 | 1.85 | 23.58 | 0.12 | 0.65 | 0.18 | 0.52 |
| 54.00 | 0.12 | 0.18 | 2.34 | 44.57 | 8.37 | 7.29 | 6.03 | 0.00 | 0.06 | 0.55 |
| 55.00 | 0.12 | 0.34 | 3.51 | 51.68 | 5.02 | 11.08 | 5.63 | 0.25 | 0.25 | 0.40 |
| 56.00 | 0.12 | 2.89 | 4.65 | 51.71 | 7.79 | 8.16 | 2.71 | 0.37 | 0.71 | 0.40 |
| 57.00 | 0.12 | 2.80 | 4.37 | 53.80 | 7.23 | 9.70 | 2.62 | 0.40 | 0.80 | 0.37 |
| 58.00 | 0.12 | 4.00 | 1.57 | 33.92 | 9.66 | 10.53 | 6.65 | 1.11 | 0.28 | 0.74 |
| 59.00 | 0.12 | 5.88 | 2.59 | 35.30 | 8.77 | 10.68 | 4.99 | 1.26 | 0.37 | 0.74 |
| 60.00 | 0.00 | 5.54 | 15.70 | 56.23 | 0.83 | 19.79 | 0.00 | 0.31 | 0.09 | 0.03 |
| 61.00 | 0.00 | 4.59 | 14.37 | 60.39 | 0.58 | 17.76 | 0.00 | 0.06 | 0.00 | 0.15 |
| 62.00 | 0.00 | 3.35 | 12.83 | 61.16 | 0.25 | 19.82 | 0.00 | 0.46 | 0.22 | 0.06 |
| 63.00 | 0.00 | 2.92 | 4.77 | 48.57 | 1.60 | 35.64 | 0.00 | 0.22 | 3.88 | 0.77 |
| 64.00 | 0.00 | 1.79 | 2.31 | 50.63 | 1.88 | 35.15 | 0.00 | 0.09 | 6.00 | 0.95 |
| 65.00 | 0.00 | 1.35 | 1.97 | 48.75 | 1.63 | 32.04 | 0.00 | 0.09 | 11.70 | 1.08 |
| 66.00 | 0.09 | 0.00 | 0.00 | 20.74 | 0.34 | 3.23 | 30.29 | 0.00 | 0.00 | 1.51 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 4.03 | 17.61 | 0.00 | 0.00 | 244.46 | 220.00 | 1.44 | 47.17 | 196.25 | 0.00 | 21.64 |
| 2.00 | 7.39 | 11.51 | 0.00 | 0.00 | 244.46 | 199.00 | 1.43 | 48.29 | 189.63 | 0.00 | 18.90 |
| 3.00 | 20.07 | 5.97 | 0.00 | 0.00 | 244.46 | 165.00 | 1.44 | 51.68 | 171.45 | 0.00 | 26.04 |
| 4.00 | 5.48 | 0.00 | 0.00 | 0.00 | 244.46 | 107.00 | 1.44 | 48.26 | 163.26 | 0.00 | 5.48 |
| 5.00 | 3.94 | 0.00 | 0.00 | 0.00 | 244.46 | 112.00 | 1.46 | 50.62 | 156.19 | 0.00 | 3.94 |
| 6.00 | 0.34 | 0.00 | 0.00 | 0.00 | 244.46 | 110.00 | 1.48 | 54.35 | 184.47 | 0.00 | 0.34 |
| 7.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 127.00 | 1.48 | 45.18 | 192.21 | 0.00 | 0.00 |
| 8.00 | 0.40 | 0.00 | 0.00 | 0.00 | 244.46 | 111.00 | 1.49 | 55.61 | 179.19 | 0.00 | 0.40 |
| 9.00 | 1.05 | 0.28 | 0.00 | 0.00 | 244.46 | 149.00 | 1.49 | 53.31 | 194.23 | 0.00 | 1.33 |
| 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 145.00 | 1.49 | 39.60 | 196.81 | 0.00 | 0.00 |
| 11.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 135.00 | 1.49 | 41.90 | 180.65 | 0.00 | 0.00 |
| 12.00 | 0.06 | 0.00 | 0.00 | 0.00 | 244.46 | 143.00 | 1.52 | 53.94 | 210.72 | 0.00 | 0.06 |
| 13.00 | 0.09 | 0.00 | 0.00 | 0.00 | 244.46 | 121.00 | 1.49 | 55.71 | 194.12 | 0.00 | 0.09 |
| 14.00 | 8.65 | 17.39 | 0.00 | 0.00 | 244.46 | 153.00 | 1.46 | 38.87 | 196.02 | 0.00 | 26.04 |
| 15.00 | 9.14 | 19.70 | 0.00 | 0.00 | 244.46 | 156.00 | 1.45 | 39.10 | 191.76 | 0.00 | 28.84 |
| 16.00 | 1.45 | 6.99 | 0.00 | 0.00 | 244.46 | 102.00 | 1.45 | 50.99 | 166.85 | 0.00 | 8.44 |
| 17.00 | 2.77 | 12.83 | 0.00 | 0.00 | 244.46 | 109.00 | 1.43 | 48.14 | 160.57 | 0.00 | 15.60 |
| 18.00 | 6.06 | 16.62 | 0.00 | 0.00 | 244.46 | 132.00 | 1.45 | 39.67 | 189.29 | 0.00 | 22.68 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 164.00 | 1.45 | 41.96 | 179.42 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 146.00 | 1.44 | 45.68 | 160.12 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 135.00 | 1.48 | 43.93 | 176.50 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 0.00 | 244.46 | 116.00 | 1.42 | 46.28 | 137.00 | 0.00 | 0.00 |
| 23.00 | 0.03 | 0.00 | 0.00 | 0.00 | 244.46 | 82.00 | 1.44 | 55.61 | 123.88 | 0.00 | 0.03 |
| 24.00 | 0.03 | 0.00 | 0.00 | 0.00 | 244.46 | 86.00 | 1.46 | 57.73 | 129.49 | 0.00 | 0.03 |
| 25.00 | 1.11 | 0.92 | 0.00 | 0.00 | 244.46 | 136.00 | 1.48 | 60.58 | 140.15 | 0.00 | 2.03 |
| 26.00 | 1.20 | 1.20 | 0.00 | 0.00 | 244.46 | 142.00 | 1.48 | 59.70 | 152.83 | 0.00 | 2.40 |
| 27.00 | 15.27 | 18.81 | 0.00 | 0.00 | 244.46 | 257.00 | 1.48 | 26.84 | 252.35 | 0.00 | 34.08 |
| 28.00 | 3.45 | 20.31 | 0.98 | 6.37 | 244.46 | 145.00 | 1.50 | 53.01 | 189.18 | 7.35 | 23.76 |
| 29.00 | 3.63 | 23.02 | 0.77 | 3.11 | 244.46 | 132.00 | 1.50 | 55.14 | 183.12 | 3.88 | 26.65 |
| 30.00 | 0.37 | 0.03 | 0.00 | 0.00 | 244.46 | 154.00 | 1.48 | 50.26 | 187.05 | 0.00 | 0.40 |
| 31.00 | 0.49 | 0.06 | 0.00 | 0.00 | 244.46 | 164.00 | 1.46 | 52.87 | 186.82 | 0.00 | 0.55 |
| 32.00 | 0.83 | 18.93 | 0.00 | 0.00 | 244.46 | 153.00 | 1.40 | 50.23 | 153.27 | 0.00 | 19.76 |
| 33.00 | 0.83 | 18.93 | 0.00 | 0.00 | 244.46 | 150.00 | 1.40 | 49.81 | 150.81 | 0.00 | 19.76 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 4.77 | 28.01 | 10.50 | 29.46 | 244.46 | 248.00 | 1.46 | 39.99 | 215.77 | 39.96 | 32.78 |
| 35.00 | 4.03 | 4.46 | 15.94 | 19.14 | 244.46 | 282.00 | 1.44 | 35.48 | 216.33 | 35.08 | 8.49 |
| 36.00 | 3.20 | 7.45 | 18.96 | 18.78 | 244.46 | 262.00 | 1.45 | 33.23 | 224.86 | 37.74 | 10.65 |
| 37.00 | 5.88 | 16.87 | 16.90 | 29.27 | 244.46 | 309.00 | 1.45 | 33.42 | 241.02 | 46.17 | 22.75 |
| 38.00 | 6.31 | 16.37 | 17.73 | 29.64 | 244.46 | 291.00 | 1.47 | 36.19 | 242.25 | 47.37 | 22.68 |
| 39.00 | 4.56 | 34.04 | 0.00 | 0.00 | 244.46 | 166.00 | 1.40 | 46.67 | 155.18 | 0.00 | 38.60 |
| 40.00 | 6.31 | 32.26 | 0.00 | 0.00 | 244.46 | 174.00 | 1.39 | 44.28 | 166.85 | 0.00 | 38.57 |
| 41.00 | 2.59 | 1.11 | 20.01 | 43.18 | 244.46 | 294.00 | 1.45 | 41.28 | 243.82 | 63.19 | 3.70 |
| 42.00 | 2.80 | 0.83 | 18.96 | 45.58 | 244.46 | 294.00 | 1.45 | 43.01 | 243.04 | 64.54 | 3.63 |
| 43.00 | 2.00 | 2.09 | 19.48 | 48.54 | 244.46 | 274.00 | 1.45 | 41.34 | 235.97 | 68.02 | 4.09 |
| 44.00 | 0.68 | 2.09 | 19.18 | 52.69 | 244.46 | 271.00 | 1.45 | 43.81 | 225.87 | 71.87 | 2.77 |
| 45.00 | 0.71 | 1.94 | 17.45 | 52.69 | 244.46 | 242.00 | 1.43 | 44.60 | 212.74 | 70.14 | 2.65 |
| 46.00 | 1.20 | 3.45 | 15.27 | 41.46 | 244.46 | 266.00 | 1.46 | 45.29 | 246.41 | 56.73 | 4.65 |
| 47.00 | 1.26 | 3.66 | 15.88 | 40.07 | 244.46 | 256.00 | 1.47 | 44.80 | 244.50 | 55.95 | 4.92 |
| 48.00 | 1.26 | 2.86 | 13.85 | 34.96 | 244.46 | 235.00 | 1.46 | 43.89 | 234.74 | 48.81 | 4.12 |
| 49.00 | 0.83 | 2.25 | 15.39 | 51.86 | 244.46 | 258.00 | 1.42 | 48.47 | 222.39 | 67.25 | 3.08 |
| 50.00 | 1.26 | 3.05 | 12.25 | 40.04 | 244.46 | 240.00 | 1.46 | 45.54 | 224.75 | 52.29 | 4.31 |
| 51.00 | 0.77 | 1.97 | 11.08 | 44.84 | 244.46 | 233.00 | 1.43 | 45.41 | 208.82 | 55.92 | 2.74 |
| 52.00 | 1.05 | 0.52 | 4.40 | 27.15 | 244.46 | 155.00 | 1.46 | 51.24 | 178.30 | 31.55 | 1.57 |
| 53.00 | 1.35 | 0.49 | 3.02 | 23.05 | 244.46 | 133.00 | 1.49 | 51.29 | 174.59 | 26.07 | 1.84 |
| 54.00 | 3.11 | 1.02 | 8.90 | 17.45 | 244.46 | 291.00 | 1.48 | 44.63 | 248.76 | 26.35 | 4.13 |
| 55.00 | 1.17 | 0.06 | 5.69 | 14.80 | 244.46 | 237.00 | 1.48 | 51.35 | 218.13 | 20.49 | 1.23 |
| 56.00 | 1.51 | 0.58 | 6.22 | 12.19 | 244.46 | 277.00 | 1.49 | 47.46 | 238.55 | 18.41 | 2.09 |
| 57.00 | 1.08 | 0.00 | 4.86 | 11.85 | 244.46 | 257.00 | 1.48 | 48.67 | 223.40 | 16.71 | 1.08 |
| 58.00 | 4.34 | 1.02 | 9.70 | 16.37 | 244.46 | 356.00 | 1.50 | 37.34 | 298.02 | 26.07 | 5.36 |
| 59.00 | 4.37 | 1.02 | 8.99 | 14.93 | 244.46 | 353.00 | 1.49 | 37.00 | 296.11 | 23.92 | 5.39 |
| 60.00 | 1.48 | 0.00 | 0.00 | 0.00 | 244.46 | 117.00 | 1.45 | 55.41 | 174.93 | 0.00 | 1.48 |
| 61.00 | 2.09 | 0.00 | 0.00 | 0.00 | 244.46 | 101.00 | 1.47 | 55.31 | 165.06 | 0.00 | 2.09 |
| 62.00 | 1.85 | 0.00 | 0.00 | 0.00 | 244.46 | 120.00 | 1.49 | 57.65 | 176.73 | 0.00 | 1.85 |
| 63.00 | 1.63 | 0.00 | 0.00 | 0.00 | 244.46 | 127.00 | 1.48 | 52.81 | 184.69 | 0.00 | 1.63 |
| 64.00 | 1.20 | 0.00 | 0.00 | 0.00 | 244.46 | 126.00 | 1.46 | 54.89 | 175.38 | 0.00 | 1.20 |
| 65.00 | 1.39 | 0.00 | 0.00 | 0.00 | 244.46 | 129.00 | 1.46 | 52.94 | 181.10 | 0.00 | 1.39 |
| 66.00 | 6.53 | 37.27 | 0.00 | 0.00 | 244.46 | 161.00 | 1.41 | 46.34 | 167.97 | 0.00 | 43.80 |

Appendix 2. Continued.

Landscape data for Scale V.

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 1.49 | 5.80 | 1.62 | 23.15 | 1.92 | 31.04 | 0.25 | 3.34 | 1.44 | 1.24 |
| 2.00 | 1.49 | 6.10 | 1.88 | 23.16 | 1.94 | 31.80 | 0.25 | 3.63 | 1.35 | 1.19 |
| 3.00 | 0.00 | 4.91 | 1.58 | 22.54 | 0.69 | 41.30 | 0.00 | 1.97 | 0.87 | 1.37 |
| 4.00 | 0.00 | 0.34 | 0.21 | 33.12 | 1.16 | 51.36 | 0.00 | 0.07 | 1.49 | 3.82 |
| 5.00 | 0.00 | 2.20 | 1.83 | 32.39 | 1.30 | 49.16 | 0.00 | 1.17 | 1.40 | 3.75 |
| 6.00 | 0.57 | 0.00 | 0.00 | 38.77 | 2.06 | 45.28 | 2.90 | 0.00 | 3.25 | 5.12 |
| 7.00 | 0.69 | 0.00 | 0.00 | 34.70 | 2.58 | 41.99 | 11.24 | 0.00 | 2.97 | 4.36 |
| 8.00 | 0.89 | 0.00 | 0.00 | 38.22 | 2.38 | 44.84 | 2.93 | 0.00 | 3.56 | 4.71 |
| 9.00 | 1.28 | 0.00 | 0.00 | 33.76 | 2.61 | 42.99 | 7.45 | 0.00 | 3.72 | 4.23 |
| 10.00 | 0.69 | 0.00 | 0.00 | 29.42 | 3.52 | 33.60 | 23.66 | 0.00 | 1.94 | 3.29 |
| 11.00 | 0.69 | 0.00 | 0.00 | 34.28 | 3.38 | 29.56 | 26.77 | 0.00 | 1.88 | 3.18 |
| 12.00 | 1.48 | 0.09 | 0.84 | 47.61 | 1.87 | 34.65 | 4.68 | 0.07 | 2.61 | 6.03 |
| 13.00 | 3.88 | 0.07 | 0.80 | 49.05 | 2.97 | 30.10 | 4.34 | 0.07 | 2.49 | 6.15 |
| 14.00 | 4.89 | 0.00 | 0.00 | 28.16 | 3.61 | 27.22 | 8.20 | 0.00 | 2.29 | 2.83 |
| 15.00 | 5.53 | 0.00 | 0.02 | 29.03 | 3.89 | 25.53 | 7.20 | 0.00 | 2.15 | 3.04 |
| 16.00 | 1.05 | 0.00 | 0.00 | 28.46 | 4.92 | 7.98 | 43.45 | 0.00 | 0.09 | 1.81 |
| 17.00 | 1.46 | 0.00 | 0.00 | 25.69 | 4.75 | 7.64 | 41.03 | 0.00 | 0.11 | 2.17 |
| 18.00 | 0.91 | 0.00 | 0.00 | 20.50 | 2.54 | 11.29 | 38.99 | 0.00 | 0.00 | 3.40 |
| 19.00 | 0.00 | 0.00 | 0.00 | 19.96 | 5.26 | 12.60 | 59.11 | 0.00 | 0.00 | 3.06 |
| 20.00 | 0.00 | 0.00 | 0.00 | 19.80 | 5.87 | 12.57 | 59.04 | 0.00 | 0.00 | 2.72 |
| 21.00 | 10.45 | 0.00 | 0.00 | 23.72 | 2.81 | 10.31 | 49.58 | 0.00 | 0.00 | 3.13 |
| 22.00 | 20.27 | 0.00 | 0.00 | 18.88 | 4.41 | 9.08 | 44.76 | 0.00 | 0.00 | 2.60 |
| 23.00 | 0.00 | 0.00 | 0.00 | 45.99 | 0.02 | 21.92 | 0.59 | 0.00 | 0.00 | 30.90 |
| 24.00 | 0.00 | 0.00 | 0.00 | 52.48 | 0.02 | 24.71 | 0.55 | 0.00 | 0.00 | 21.17 |
| 25.00 | 2.38 | 0.00 | 0.00 | 13.17 | 5.97 | 4.55 | 68.89 | 0.00 | 0.00 | 1.39 |
| 26.00 | 3.15 | 0.00 | 0.00 | 13.48 | 5.78 | 4.23 | 69.55 | 0.00 | 0.00 | 1.39 |
| 27.00 | 3.25 | 0.00 | 0.00 | 15.93 | 3.61 | 8.66 | 24.53 | 0.00 | 0.00 | 4.00 |
| 28.00 | 0.68 | 1.62 | 5.60 | 35.88 | 1.12 | 13.44 | 4.02 | 0.36 | 0.39 | 0.18 |
| 29.00 | 0.75 | 2.67 | 6.54 | 35.25 | 0.71 | 13.32 | 3.09 | 0.34 | 0.37 | 0.18 |
| 30.00 | 4.48 | 0.00 | 0.00 | 13.81 | 14.10 | 5.60 | 56.07 | 0.00 | 0.00 | 2.54 |
| 31.00 | 2.72 | 0.00 | 0.00 | 14.38 | 10.86 | 5.72 | 58.76 | 0.00 | 0.00 | 4.16 |
| 32.00 | 0.07 | 0.00 | 0.00 | 15.95 | 4.30 | 7.75 | 52.52 | 0.00 | 0.00 | 2.60 |
| 33.00 | 0.07 | 0.00 | 0.00 | 16.04 | 4.00 | 8.43 | 51.91 | 0.00 | 0.00 | 3.02 |

| plot no. | water | conifer | savannah | midgrasslb | wetland/rip | midgrassmb | hay/pasture | ponderosa pine | shrubs | bare soil |
|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 5.39 | 0.00 | 0.00 | 5.14 | 9.33 | 1.72 | 7.72 | 0.00 | 0.00 | 0.27 |
| 35.00 | 21.39 | 0.00 | 0.00 | 8.12 | 11.11 | 2.74 | 7.43 | 0.00 | 0.00 | 0.27 |
| 36.00 | 18.06 | 0.00 | 0.00 | 8.82 | 10.24 | 2.70 | 6.58 | 0.00 | 0.00 | 0.28 |
| 37.00 | 7.32 | 0.00 | 0.05 | 9.74 | 8.94 | 2.36 | 4.39 | 0.00 | 0.00 | 0.14 |
| 38.00 | 1.26 | 0.00 | 0.23 | 11.95 | 8.23 | 5.46 | 1.83 | 0.00 | 0.00 | 4.28 |
| 39.00 | 1.26 | 0.00 | 0.00 | 18.40 | 1.07 | 7.68 | 29.42 | 0.00 | 0.00 | 1.40 |
| 40.00 | 1.26 | 0.00 | 0.00 | 19.48 | 1.10 | 4.91 | 28.14 | 0.00 | 0.00 | 1.10 |
| 41.00 | 5.67 | 0.00 | 0.00 | 11.54 | 12.69 | 2.99 | 3.64 | 0.00 | 0.00 | 0.07 |
| 42.00 | 1.71 | 0.00 | 0.00 | 12.55 | 13.17 | 2.26 | 2.88 | 0.00 | 0.00 | 0.07 |
| 43.00 | 0.04 | 0.00 | 0.04 | 11.56 | 9.85 | 3.70 | 2.31 | 0.00 | 0.00 | 3.15 |
| 44.00 | 0.00 | 0.00 | 0.02 | 16.91 | 9.14 | 2.13 | 2.03 | 0.00 | 0.00 | 0.64 |
| 45.00 | 0.00 | 0.00 | 0.02 | 21.48 | 8.73 | 1.92 | 1.32 | 0.00 | 0.00 | 0.20 |
| 46.00 | 0.02 | 0.07 | 1.53 | 24.21 | 8.18 | 3.18 | 7.24 | 0.00 | 0.00 | 0.20 |
| 47.00 | 0.02 | 0.07 | 1.55 | 24.21 | 8.30 | 3.52 | 8.09 | 0.00 | 0.00 | 0.25 |
| 48.00 | 0.21 | 0.09 | 1.55 | 26.76 | 7.75 | 3.47 | 10.58 | 0.00 | 0.00 | 0.60 |
| 49.00 | 0.02 | 0.00 | 0.27 | 24.30 | 9.01 | 2.52 | 1.39 | 0.00 | 0.00 | 0.05 |
| 50.00 | 0.02 | 0.07 | 2.01 | 29.65 | 6.72 | 11.06 | 1.78 | 0.00 | 0.00 | 0.20 |
| 51.00 | 0.02 | 0.04 | 0.94 | 28.16 | 6.58 | 10.86 | 0.82 | 0.00 | 0.00 | 0.34 |
| 52.00 | 0.00 | 2.33 | 8.80 | 32.05 | 3.00 | 19.84 | 0.57 | 0.55 | 0.28 | 0.92 |
| 53.00 | 0.00 | 2.65 | 10.86 | 32.36 | 3.06 | 19.22 | 1.23 | 0.43 | 0.18 | 1.32 |
| 54.00 | 0.07 | 2.65 | 3.50 | 41.23 | 7.86 | 11.34 | 5.51 | 0.34 | 0.43 | 0.46 |
| 55.00 | 0.07 | 1.72 | 3.54 | 48.30 | 5.23 | 12.25 | 4.57 | 0.18 | 0.46 | 0.32 |
| 56.00 | 0.07 | 3.40 | 5.80 | 45.97 | 7.96 | 12.20 | 3.54 | 0.32 | 1.69 | 0.52 |
| 57.00 | 0.07 | 3.04 | 5.44 | 49.72 | 6.95 | 12.37 | 3.27 | 0.32 | 1.80 | 0.41 |
| 58.00 | 0.07 | 5.26 | 3.68 | 38.10 | 7.93 | 10.60 | 5.69 | 1.19 | 0.60 | 0.64 |
| 59.00 | 0.07 | 5.72 | 4.53 | 39.08 | 7.86 | 11.57 | 5.07 | 1.10 | 0.62 | 0.57 |
| 60.00 | 0.00 | 9.10 | 15.54 | 54.74 | 1.00 | 17.16 | 0.00 | 1.00 | 0.20 | 0.11 |
| 61.00 | 0.00 | 4.18 | 13.12 | 61.05 | 0.62 | 19.11 | 0.00 | 0.09 | 0.25 | 0.12 |
| 62.00 | 0.00 | 5.24 | 14.63 | 56.75 | 0.52 | 20.09 | 0.00 | 1.05 | 0.27 | 0.04 |
| 63.00 | 0.00 | 3.08 | 3.98 | 52.82 | 1.64 | 28.27 | 0.00 | 0.75 | 6.83 | 1.12 |
| 64.00 | 0.32 | 1.97 | 3.91 | 52.43 | 1.81 | 29.56 | 0.00 | 0.14 | 6.56 | 2.26 |
| 65.00 | 0.00 | 1.81 | 3.36 | 51.73 | 1.74 | 26.28 | 0.00 | 0.14 | 10.49 | 3.08 |
| 66.00 | 1.21 | 0.00 | 0.00 | 18.86 | 1.17 | 4.28 | 27.75 | 0.00 | 0.00 | 0.94 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 9.03 | 19.68 | 0.00 | 0.00 | 423.23 | 394.00 | 1.48 | 42.98 | 211.80 | 0.00 | 28.71 |
| 2.00 | 11.96 | 15.24 | 0.00 | 0.00 | 423.23 | 401.00 | 1.49 | 41.99 | 219.45 | 0.00 | 27.20 |
| 3.00 | 15.29 | 9.48 | 0.00 | 0.00 | 423.23 | 342.00 | 1.46 | 45.11 | 192.17 | 0.00 | 24.77 |
| 4.00 | 8.43 | 0.00 | 0.00 | 0.00 | 423.23 | 200.00 | 1.47 | 55.94 | 170.71 | 0.00 | 8.43 |
| 5.00 | 6.79 | 0.00 | 0.00 | 0.00 | 423.23 | 247.00 | 1.47 | 51.15 | 180.50 | 0.00 | 6.79 |
| 6.00 | 1.96 | 0.09 | 0.00 | 0.00 | 423.23 | 220.00 | 1.49 | 51.78 | 193.85 | 0.00 | 2.05 |
| 7.00 | 0.84 | 0.64 | 0.00 | 0.00 | 423.23 | 200.00 | 1.49 | 49.44 | 184.26 | 0.00 | 1.48 |
| 8.00 | 2.12 | 0.36 | 0.00 | 0.00 | 423.23 | 236.00 | 1.50 | 50.38 | 198.91 | 0.00 | 2.48 |
| 9.00 | 2.03 | 1.94 | 0.00 | 0.00 | 423.23 | 224.00 | 1.49 | 46.94 | 195.92 | 0.00 | 3.97 |
| 10.00 | 1.78 | 2.10 | 0.00 | 0.00 | 423.23 | 225.00 | 1.48 | 45.87 | 182.05 | 0.00 | 3.88 |
| 11.00 | 0.00 | 0.25 | 0.00 | 0.00 | 423.23 | 199.00 | 1.47 | 47.02 | 172.46 | 0.00 | 0.25 |
| 12.00 | 0.09 | 0.00 | 0.00 | 0.00 | 423.23 | 241.00 | 1.49 | 55.28 | 199.42 | 0.00 | 0.09 |
| 13.00 | 0.09 | 0.00 | 0.00 | 0.00 | 423.23 | 241.00 | 1.49 | 53.54 | 200.59 | 0.00 | 0.09 |
| 14.00 | 6.06 | 16.75 | 0.00 | 0.00 | 423.23 | 247.00 | 1.46 | 39.00 | 186.40 | 0.00 | 22.81 |
| 15.00 | 6.26 | 17.35 | 0.00 | 0.00 | 423.23 | 261.00 | 1.45 | 41.23 | 189.96 | 0.00 | 23.61 |
| 16.00 | 2.31 | 9.92 | 0.00 | 0.00 | 423.23 | 218.00 | 1.46 | 47.98 | 176.48 | 0.00 | 12.23 |
| 17.00 | 3.43 | 13.72 | 0.00 | 0.00 | 423.23 | 226.00 | 1.45 | 45.79 | 177.13 | 0.00 | 17.15 |
| 18.00 | 4.30 | 18.08 | 0.00 | 0.00 | 423.23 | 230.00 | 1.45 | 42.54 | 171.49 | 0.00 | 22.38 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 | 423.23 | 282.00 | 1.48 | 40.18 | 186.01 | 0.00 | 0.00 |
| 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 423.23 | 277.00 | 1.49 | 40.42 | 181.86 | 0.00 | 0.00 |
| 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 423.23 | 197.00 | 1.45 | 43.35 | 157.23 | 0.00 | 0.00 |
| 22.00 | 0.00 | 0.00 | 0.00 | 0.00 | 423.23 | 205.00 | 1.43 | 42.18 | 139.73 | 0.00 | 0.00 |
| 23.00 | 0.16 | 0.43 | 0.00 | 0.00 | 423.23 | 160.00 | 1.48 | 56.62 | 136.23 | 0.00 | 0.59 |
| 24.00 | 0.37 | 0.69 | 0.00 | 0.00 | 423.23 | 153.00 | 1.46 | 57.48 | 129.82 | 0.00 | 1.06 |
| 25.00 | 1.37 | 2.28 | 0.00 | 0.00 | 423.23 | 277.00 | 1.49 | 55.71 | 165.85 | 0.00 | 3.65 |
| 26.00 | 1.28 | 1.16 | 0.00 | 0.00 | 423.23 | 277.00 | 1.49 | 56.75 | 163.00 | 0.00 | 2.44 |
| 27.00 | 17.28 | 22.74 | 0.00 | 0.00 | 423.23 | 411.00 | 1.49 | 29.80 | 240.71 | 0.00 | 40.02 |
| 28.00 | 3.95 | 22.08 | 1.64 | 9.07 | 423.23 | 309.00 | 1.48 | 47.96 | 191.58 | 10.71 | 26.03 |
| 29.00 | 3.88 | 24.00 | 1.24 | 7.66 | 423.23 | 301.00 | 1.48 | 48.59 | 190.03 | 8.90 | 27.88 |
| 30.00 | 0.89 | 2.51 | 0.00 | 0.00 | 423.23 | 269.00 | 1.46 | 46.76 | 187.69 | 0.00 | 3.40 |
| 31.00 | 1.21 | 2.19 | 0.00 | 0.00 | 423.23 | 291.00 | 1.47 | 47.39 | 192.88 | 0.00 | 3.40 |
| 32.00 | 1.24 | 15.57 | 0.00 | 0.00 | 423.23 | 267.00 | 1.44 | 48.25 | 160.67 | 0.00 | 16.81 |
| 33.00 | 1.03 | 15.50 | 0.00 | 0.00 | 423.23 | 243.00 | 1.43 | 48.57 | 153.54 | 0.00 | 16.53 |

| plot no. | buildings/paved | urban veg | tallgrass/wet | tallgrass | area(ha) | num patches | dlfd | contagion | perimeter/area | tallgrass(total) | urban (total) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34.00 | 5.74 | 31.88 | 8.52 | 24.30 | 423.23 | 415.00 | 1.46 | 39.09 | 199.68 | 32.82 | 37.62 |
| 35.00 | 4.18 | 11.22 | 13.42 | 20.12 | 423.23 | 473.00 | 1.45 | 33.06 | 222.37 | 33.54 | 15.40 |
| 36.00 | 5.46 | 17.28 | 13.85 | 16.73 | 423.23 | 467.00 | 1.45 | 32.69 | 217.05 | 30.58 | 22.74 |
| 37.00 | 4.94 | 19.13 | 14.93 | 28.04 | 423.23 | 437.00 | 1.44 | 37.91 | 211.02 | 42.97 | 24.07 |
| 38.00 | 6.45 | 19.06 | 14.93 | 26.31 | 423.23 | 469.00 | 1.47 | 35.26 | 231.18 | 41.24 | 25.51 |
| 39.00 | 5.62 | 35.15 | 0.00 | 0.00 | 423.23 | 292.00 | 1.45 | 42.25 | 177.45 | 0.00 | 40.77 |
| 40.00 | 6.52 | 37.48 | 0.00 | 0.00 | 423.23 | 307.00 | 1.45 | 43.02 | 180.76 | 0.00 | 44.00 |
| 41.00 | 3.24 | 3.56 | 19.59 | 37.01 | 423.23 | 464.00 | 1.45 | 37.10 | 237.86 | 56.60 | 6.80 |
| 42.00 | 2.22 | 2.65 | 19.36 | 43.13 | 423.23 | 486.00 | 1.45 | 40.83 | 241.88 | 62.49 | 4.87 |
| 43.00 | 4.09 | 2.17 | 15.41 | 47.70 | 423.23 | 475.00 | 1.47 | 43.32 | 239.48 | 63.11 | 6.26 |
| 44.00 | 1.46 | 1.46 | 16.04 | 50.19 | 423.23 | 426.00 | 1.44 | 46.62 | 220.88 | 66.23 | 2.92 |
| 45.00 | 1.24 | 1.44 | 15.61 | 48.05 | 423.23 | 418.00 | 1.45 | 47.78 | 215.82 | 63.66 | 2.68 |
| 46.00 | 1.10 | 2.51 | 13.30 | 38.47 | 423.23 | 400.00 | 1.45 | 44.72 | 225.48 | 51.77 | 3.61 |
| 47.00 | 1.10 | 2.63 | 12.66 | 37.60 | 423.23 | 399.00 | 1.46 | 44.05 | 227.36 | 50.26 | 3.73 |
| 48.00 | 1.16 | 3.02 | 11.38 | 33.44 | 423.23 | 390.00 | 1.47 | 42.62 | 226.51 | 44.82 | 4.18 |
| 49.00 | 0.96 | 1.56 | 14.95 | 44.96 | 423.23 | 401.00 | 1.44 | 49.12 | 211.54 | 59.91 | 2.52 |
| 50.00 | 1.10 | 2.36 | 11.56 | 33.48 | 423.23 | 365.00 | 1.47 | 45.73 | 215.04 | 45.04 | 3.46 |
| 51.00 | 0.92 | 1.71 | 12.37 | 37.24 | 423.23 | 356.00 | 1.45 | 48.67 | 202.15 | 49.61 | 2.63 |
| 52.00 | 0.98 | 1.16 | 5.85 | 23.66 | 423.23 | 309.00 | 1.48 | 46.22 | 202.60 | 29.51 | 2.14 |
| 53.00 | 1.12 | 1.80 | 5.39 | 20.41 | 423.23 | 316.00 | 1.47 | 44.37 | 208.82 | 25.80 | 2.92 |
| 54.00 | 2.58 | 2.08 | 6.38 | 15.57 | 423.23 | 452.00 | 1.49 | 42.89 | 245.70 | 21.95 | 4.66 |
| 55.00 | 2.33 | 3.11 | 4.96 | 12.96 | 423.23 | 402.00 | 1.49 | 47.20 | 224.18 | 17.92 | 5.44 |
| 56.00 | 2.58 | 0.59 | 5.14 | 10.24 | 423.23 | 463.00 | 1.50 | 43.56 | 250.04 | 15.38 | 3.17 |
| 57.00 | 1.90 | 0.59 | 4.94 | 9.17 | 423.23 | 450.00 | 1.50 | 45.87 | 242.91 | 14.11 | 2.49 |
| 58.00 | 3.04 | 0.59 | 7.11 | 15.50 | 423.23 | 522.00 | 1.49 | 39.50 | 271.17 | 22.61 | 3.63 |
| 59.00 | 3.18 | 0.59 | 6.86 | 13.17 | 423.23 | 523.00 | 1.50 | 39.32 | 274.48 | 20.03 | 3.77 |
| 60.00 | 1.17 | 0.00 | 0.00 | 0.00 | 423.23 | 250.00 | 1.47 | 51.95 | 189.57 | 0.00 | 1.17 |
| 61.00 | 1.46 | 0.00 | 0.00 | 0.00 | 423.23 | 193.00 | 1.50 | 57.28 | 177.45 | 0.00 | 1.46 |
| 62.00 | 1.42 | 0.00 | 0.00 | 0.00 | 423.23 | 205.00 | 1.48 | 53.87 | 190.41 | 0.00 | 1.42 |
| 63.00 | 1.53 | 0.00 | 0.00 | 0.00 | 423.23 | 214.00 | 1.47 | 51.16 | 186.85 | 0.00 | 1.53 |
| 64.00 | 1.03 | 0.00 | 0.00 | 0.00 | 423.23 | 217.00 | 1.44 | 54.31 | 179.79 | 0.00 | 1.03 |
| 65.00 | 1.37 | 0.00 | 0.00 | 0.00 | 423.23 | 219.00 | 1.48 | 50.17 | 188.86 | 0.00 | 1.37 |
| 66.00 | 6.49 | 39.29 | 0.00 | 0.00 | 423.23 | 293.00 | 1.44 | 44.22 | 174.54 | 0.00 | 45.78 |