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LANDSCAPE ANALYSIS AND BREEDING BIRDS

by

© CHARLES HARRISON KARIUKI MUCHOKI, BSc., Dip.

A thesis submitted to the Faculty of
Graduate Studies and Research in partial fulfilment
of the requirements for the degree of
Master of Science

Department of Biology
Carleton university
Ottawa, Ontario
June , 1987

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Carleton University
June, 1987

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ABSTRACT

I studied two landscapes differing in agricultural intensity with a view to establish whether wooded patches were related to landscape patterns. I used two approaches: woodlot analysis and landscape classification. I indexed the amount of agriculture, wood and degree of isolation in woodlots and landscapes. These variables appeared to represent the major differences between the two landscapes as portrayed by thematic mapper imagery. Further, I needed to know if the wooded patch properties were of ecological significance to animals, therefore I used breeding bird species in a multiple regression to test this significance. Results show that wooded patches are related to landscape patterns. On the other hand, breeding bird species are directly related to properties of wooded patches and therefore breeding bird species are related to landscape patterns. Future regional conservation of wildlife and ecological land-use planning can therefore be focused on landscape patterns.

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INTRODUCTION

All over the world, human activities such as agriculture, urbanisation and industry continue to fragment natural habitats to an extent that little exists of the original vegetation biomes, a view shared by (Curtis 1956, I.U.C.N. 1980, Bowen and Burgess 1981, Harris 1984) among others. Many ecologists have shifted from the earlier held view of homogeneous environment to one of heterogeneous or patchy environment (Merriam 1984, Den Boer 1981, Hassel 1980, Lomniki 1980, Hansson 1979 & 1977, Levin 1976 and Wiens 1976). Landscape ecology originated in Central Europe out of the holistic approach adopted by geographers, landscape planners and resource managers in their attempt to bridge the gaps between natural, agricultural, human and urban systems (Naveh and Lieberman 1984). Risser, Karr and Forman (1984) state that "Conceptually, landscape ecology considers the development and dynamics of spatial heterogeneity, spatial and temporal interactions and exchanges across heterogeneous landscapes, influences of spatial heterogeneity on biotic and abiotic processes, and management of spatial heterogeneity". Further to this Forman and Godron (1986) simplify the concepts of landscape ecology to one of exploring how a heterogeneous combinations of ecosystems such as woods, marshes, corridors and villages is structured, functions and changes.

In landscape ecological studies, the term landscape is introduced which is defined according to Forman and Godron (1986) as "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout and varying in size down to a few kilometers in diameter". They further point out that a landscape consists of patches, corridors and a matrix. The matrix is the most extensive and most continuous landscape element and plays the predominant role in landscape dynamics. Opdam (1984) and Zonneveld (1979) view a landscape differently. Both emphasise that landscapes be defined on the basis of soil, vegetation and faunal attributes.

Extracting information from landscapes requires specialised tools. Remote sensing has been invaluable, especially with multispectral imaging, due to its synoptic coverage (i.e. provides a general view of a whole) and its repetitiveness (Hilwig 1979, Naveh and Lieberman 1984). Remote sensing involves recording and analysing electromagnetic energy: visible light, infrared, or any other form of transmitted energy (Greigor 1986). Greigor further points out that although the eye is the original remote sensor, this term includes everything from handheld cameras to aircraft radar and satellite imaging systems. Remote sensing has applications in soil mapping, exploration geology, land use planning, hydrology, ecological monitoring, thermal pollution, vegetation

mapping, forest inventory, wetlands mapping, crop inventory, water quality and others, see (Naveh and Lieberman 1984, Risser et al. 1984, Forman and Godron 1986, Bowen and Burgess 1981, Hielkema 1981, Antrop 1984, Folving 1984, Howard and Michell 1980, Lillesand and Kiefer 1979, McCuaig and Manning 1982, Becket and Webster 1970, Anderson et al. 1976, Ishowy 1975, Thie and Ironside 1976, Bale et al. 1974, and Colwell 1971) for reviews.

Most electrical optical sensor systems in use today belong to the class of sensor known as multispectral scanners (MSS) (Greigor 1986, Naveh and Lieberman 1984) because they simultaneously record energy from several portions of the electromagnetic spectrum. The recently introduced advanced multispectral scanner is called thematic mapper and has a spatial resolution of 30 metres. Further to this, the SPOT system (Chevrel et al. 1981) launched by the French National Space Program will give images with a spatial resolution of 10 to 20 metres. This advancement of remote sensors will provide an enormous wealth of knowledge in our attempt to analyse the spatial and temporal processes operating in our human dominated landscapes. However, aerial photography among other remote sensing tools still remains the single most used technique world-wide for analysing and describing landscapes.

One of the products of remote sensing techniques for looking at landscapes in a holistic approach is the

ecological landscape classification map and its accompanying data. The holistic approach begins with the hypothesis that the environment is a fully integrated (holistic) entity, that can be studied as a "whole" (Zonneveld 1979). Opdam (1984) further points out that the holistic concept implies that landscape units are delineated on the basis of soil, vegetation and faunal attributes. The patch, also called the ecotope, is viewed as the basic unit of the landscape. It is spatially well defined and therefore mappable (Naveh and Lieberman 1984). The classical example of the holistic approach to practical land survey and evaluation or the equivalent of ecological landscape classification is the "land system" approach applied in Australia by the Directorate of Survey of British Commonwealth (Wright 1971, Christian and Steward 1964) and in Canada, "The Biophysical Land Classification" (Thie and Ironside 1976, Wiken and Ironside 1977).

Ecosystem processes in man dominated landscapes can be assessed through identification and quantification of landscape variables (Bowen and Burgess 1981). Using landscape variables in some studies has additional advantage in that the properties of ecosystems emergent at that scale may influence populations in ways not easily detected with studies made at smaller scale. For example, a landscape with a few large forest islands might support a larger population density of certain bird species than a

nearby landscape with a larger number of smaller islands, even though the forest of both areas are composed of the same tree species and cover the same area (Freemark and Merriam 1986).

One goal of landscape ecology is to quantify the various spatial, temporal and functional aspects of landscape (Klopatek et al. 1979) in order to develop data bases for evaluating and anticipating regional environmental impacts of land use activities which may have long term effects. In an attempt to fulfill this goal, especially on effects of forest fragmentation some contributions have been made (Forman et al. 1976, Galli et al. 1976, Levenson 1981, Whitcomb et al. 1981, Bowen and Burgess 1981, Burgess and Sharpe 1981, Blake and Karr 1984, Opdam 1984, Freemark and Merriam 1986, Askiñs et al. 1987). These studies have mainly focused on forest island dynamics and a further testing of biogeographic theory. As a contribution to landscape ecology, there is need to analyse patch and landscape properties simultaneously in order to establish whether patch properties can be related to landscape patterns. This relationship if it exists is important because future regional conservation of wildlife and ecological landscape planning can be based on landscape patterns. My study has taken this direction whereby I have analysed two landscapes differing in agricultural intensity (Figure 1). I used two approaches : woodlot analysis and landscape classification.

I indexed the amount of agriculture, wood and degree of isolation in woodlots and landscapes. These variables appeared to represent the major differences between the two landscapes as portrayed by thematic mapper imagery. Further to this, I needed to know if patch properties are related to landscape patterns, then are these patch properties of ecological significance to animals? Therefore I validated the ecological significance of patch properties using breeding bird species.

Figure 1. The study plan

Figure 2. The study area : map extracted from thematic
mapper imagery, track 16, row 28, July 1984.

- KEY:
- A MORE INTENSE AGRICULTURE LANDSCAPE
 - B LESS INTENSE AGRICULTURE LANDSCAPE
 - DRAINAGE
 - TOWNSHIP

Figure 3. Demonstration of woodlot and landscape variables

Landscape

W	-	Extensive wood	A	-	Extensive agriculture		
W1	-	W2	Longest axis	A1	-	A2	Longest axis
W3	-	W4	Perimeter				
W5	-	W6	Distance	(A)	-	Interior index	
(W)	-		Interior index				

Woodlot

A	-	Agriculture	D1	-	D2	Distance	
W	-	Woodlot	P1	-	P2	Perimeter	
L1	-	L2	Longest axis	H1	-	H2	Hedgerow / length
IW	-	Isolated woodlots					
(W)	-		Interior index				

LANDSCAPE

0 25 5.0
Km

WOODLOT

0 m 500

M E T H O D S

Air Photo Analysis

I chose two landscapes in the Ottawa valley, Canada which were subject to more intense agriculture (Arnprior) and less intense agriculture (Renfrew) (see figure 1 and 2). A set of woodlots was selected in each landscape so that there were pairs matching in area in each landscape. Woodlots ranged in area from 3ha to 220ha. The Arnprior set of woodlots were studied by Freemark (1983).

I used panchromatic black and white airphotos at a scale of 1: 25,000 of 1978 from the National Airphoto Library for the two landscapes. First, I did preliminary interpretation of the airphotos in each landscape visually and stereoscopically with the aid of 1: 50,000 topographic maps. Then I did detailed analysis using photo characteristics such as tone, texture and pattern (van Zuidam 1978) to identify various elements of the landscape.

I quantified the following patch variables from the airphotos (Table 1 and demonstrated on Figure 3): longest axis of woodlot, perimeter of woodlot, percent cover of agriculture, distance to nearest woodlot, interior index, number of isolated woodlots, number of hedgerows and length of hedgerows, (see Lynch and Whigham 1984, Bowen and Burgess 1981 for related works). I chose these variables

in order to determine the amount of agriculture, wood and degree of isolation in the wooded patches.

I used a ruler to measure longest axis of woodlot, length of hedgerows and distance to nearest woodlot. I measured perimeter by a marked fibre string. I measured interior index by a compass. I estimated percent agriculture in a gridded overlay on a 1.5 km x 1.5 km grid for the smallest woodlots, in a 3 km x 3 km grid for the intermediate woodlots and in 8 km x 8 km grid for the largest woodlots, (see Helliwell 1976b and Arnold 1983 for related studies). I varied the grid size to avoid overlap of the adjacent woodlots which were also to be analysed. I also used the same analysis frame for measuring : number of isolated woodlots, distance to nearest woodlots, number of hedgerows and length of hedgerows.

Table 2. Definitions of landscape variables measured for
Arnprior and Renfrew landscapes.

LONGEST AXIS OF EXTENSIVE AGRICULTURE : The longest dimension (in km) of extensive agriculture in a landscape.

PERCENT COVER OF EXTENSIVE AGRICULTURE : Percent cover of extensive agriculture in a landscape.

PERCENT COVER OF EXTENSIVE WOODS : Percent cover of extensive woods in a landscape.

LONGEST AXIS OF EXTENSIVE WOODS : The longest dimension (in km) of extensive woods in a landscape.

PERIMETER OF EXTENSIVE WOODS : The length (km) of the edge of extensive woods in a landscape.

INTERIOR INDEX OF EXTENSIVE WOODS : Area in (ha) of largest circle that fits extensive woods.

INTERIOR INDEX OF EXTENSIVE AGRICULTURE : Area in hectares of largest circle that fits inside extensive agriculture area.

NUMBER OF ISOLATED WOODS : The total number of isolated woods in a landscape.

PERCENT COVER OF WOODS : Percent cover of wood in a landscape.

PERCENT COVER OF AGRICULTURE : Percent cover of agriculture in a landscape.

DISTANCE BETWEEN EXTENSIVE WOODS : The shortest distance (km) from the edge of an extensive forest to the nearest edge of another extensive forest.

Thematic Mapper Image Analysis

I used thematic mapper imagery of July 1984 including visible spectrum bands Blue, Green and Red (.4, .5 and .7 microns) respectively from the Canada Center for Remote Sensing. The imagery had a scale of 1: 250,000 and a spatial resolution of 30 metres. I interpreted image properties visually from spectral reflectivity curves (Howard 1984, Lillesand and Kiefer 1979 among others). I based landscape dimensions on valley alluvial terrain where agriculture is mainly concentrated. I excluded the precambrian hilly terrain where agriculture is absent. I further made a boundary between the two landscapes based on differences in agricultural intensities as portrayed by the thematic mapper image.

Ground Survey

I did a reconnaissance air survey for the two landscapes and surrounding environment using a single engine low flying aircraft to get preliminary groundtruth, (see Rowe and Sheard 1981 for related studies). On the ground I also visited 25 sites in Arnprior and 22 sites in Renfrew. I used a thematic mapper image, a magnifying lens and a topographic map to identify individual sites. I then interpreted the components of the site in terms of its

colours from the thematic mapper imagery and compared it with attributes of the land surface (land cover) of the same site. I developed a series of image characteristics versus attributes of the land surface as a key for interpretation of the colour image and extrapolation to the entire landscapes.

Landscape Classification

To develop a landscape classification, I used a gridded overlay with cells measuring 5mm by 5mm (which on the ground was 1.25km by 1.25km or 156.25 ha.) for analysis of landscape elements. The analysis involved estimating percentage cover for each landscape element in the grid cell (see Kwak and Reyriink 1984, Kalkhoven and Opdam 1984, Bruylants et al. 1984 for related works). I analysed 288 grid cells in the whole of the Arnprior landscape and 256 in the Renfrew landscape and classified landscape elements into eight classes. I quantified variables from the image by methods similar to those used during woodlot variable analysis and measured the variables described in Table 2 and demonstrated on Figure 3.

Table 2. Definitions of landscape variables measured for Arnprior and Renfrew landscapes.

LONGEST AXIS OF EXTENSIVE AGRICULTURE : The longest dimension (in km) of extensive agriculture in a landscape.

PERCENT COVER OF EXTENSIVE AGRICULTURE : Percent cover of extensive agriculture in a landscape.

PERCENT COVER OF EXTENSIVE WOODS : Percent cover of extensive woods in a landscape.

LONGEST AXIS OF EXTENSIVE WOODS : The longest dimension (in km) of extensive woods in a landscape.

PERIMETER OF EXTENSIVE WOODS : The length (km) of the edge of extensive woods in a landscape.

INTERIOR INDEX OF EXTENSIVE WOODS : Area in (ha) of largest circle that fits extensive woods.

INTERIOR INDEX OF EXTENSIVE AGRICULTURE : Area in hectares of largest circle that fits inside extensive agriculture area.

NUMBER OF ISOLATED WOODS : The total number of isolated woods in a landscape.

PERCENT COVER OF WOODS : Percent cover of wood in a landscape.

PERCENT COVER OF AGRICULTURE : Percent cover of agriculture in a landscape.

DISTANCE BETWEEN EXTENSIVE WOODS : The shortest distance (km) from the edge of an extensive forest to the nearest edge of another extensive forest.

Data Analysis

I used SPSS-x Factor analysis (Norusis 1985) to analyse the data. Factor analysis is a multivariate statistical technique used to identify a relatively small number of factors that can be used to represent relationships among interrelated variables (Norusis 1985, Gauch 1982, Legendre and Legendre 1983). The variables area and interior index were log transformed. Percent agriculture was transformed into arcsine percent agriculture. These transformations were necessary in order to linearise the data and make the variances independent of the means (Sokal and Rohlf 1981). Factor analysis usually proceeds in four steps, first the correlation matrix for all the variables is computed, the second step is extraction of the number of factors necessary to represent the data, the third step is rotation which focuses on transforming factors to make them more interpretable and the fourth step computes scores for each factor. Further to this, I performed a multiple regression (Norusis 1985) on breeding bird species numbers of each woodlot as a dependent variable against factor scores of woodlots as independent variables.

There was need for a factor re-analysis due to the

illogical grouping of variables in factor 1 whereby all variables related to area of fragments were increasing together with Distance to nearest woodlot (DSTNWL) which cannot be so. In factor 1, several variables related to lack of fragmentation but DSTNWL measured fragmentation and isolation. The re-analysis made only one single change, i.e. DSTNWL to reciprocal DSTNWL or INDSTNWL which was a reasonable measure of lack of fragmentation. Re-analysis continued as before with all other variables remaining unchanged.

RESULTS

Air Photo Analysis

Woodlot variables from the Arnprior landscape (Table 3) show high mean values for percent agriculture, number of isolated woods and distance to nearest woodlot. Renfrew landscape woodlots (Table 4) show high mean values for perimeter and length of hedgerows. The mean value for the longest axis (Table 3 & 4) does not differ remarkably due to the matching up of woodlot areas in the two landscapes. The 8 hectare woodlot in Arnprior (Table 3), had a low measurement of longest axis due to its elongated triangular shape. This may also have affected its interior index. The 4 hectare woodlot (Table 3) had a high distance to nearest woodlot compared to its matched pair (Table 4) due to its isolation. The 8 and 14 hectare woodlots (Table 4) have the same longest axis because of similar shapes.

Arnprior landscape (Table 3) shows higher mean values for percent agriculture, number of isolated woods and distance to nearest woodlot. The corresponding values for Renfrew landscape are lower and as regards number of isolated woods and distance to nearest woodlot, they are almost half the values for Arnprior landscape. Further to this, the perimeters of woodlots 5 ha, 8 ha, 16 ha and 220

Table 3 . Woodlot variables measured from air photos for the Arnprior landscape.

Variables	Woodlot areas in hectares								$\bar{x}$	s.d.
	4	5	8	13	16	44	58	220		
LGAX	250	300	200	600	625	1125	1875	2000	871.8	718.3
RRMWL	825	675	450	1525	1925	3300	6375	4975	2606.3	2117.7
AGR *	89	83	81	87	85	83	80	81	83.6	18.1
ISLWL*	1	3	2	3	5	8	9	9	5.0	4.2
DSTNWL	588	213	600	313	300	188	439	567	401.0	169.9
INTDEX	3	4	1	11	10	24	20	57	16.3	18.3
HEDG	2	2	1	1	1	3	2	7	2.4	1.9
LHEDG	620	525	150	100	120	925	200	950	448.8	357.3

* $p \leq .05$ compared to Renfrew

Table 4 . Woodlot variables measured from air photos for the Renfrew landscape.

Variables	Woodlot areas in hectares								$\bar{x}$	s.d.
	3	7	8	14	17	38	54	175		
LGAX	180	324	468	468	792	900	1908	1990	878.8	612.5
PRMWL	576	1288	1368	1692	3024	3224	5472	8280	3115.5	2694.3
AGR *	72	83	78	73	77	80	50	70	73.0	9.4
ISLWL*	3	3	1	3	2	3	2	3	2.5	0.7
DSTNWL	234	126	216	342	324	270	324	216	256.0	74.1
INTDEX	3	5	4	7	10	15	15	49	13.5	15.0
HEDG	1	1	2	4	3	4	3	3	2.6	1.2
LHEDG	180	130	216	432	288	1296	1240	900	585.3	485.8

* $p \leq .05$ compared to Arnprior

in Arnprior landscape are almost half the perimeters of their matching pairs in Renfrew landscape. Wilcoxon Signed- Ranks Test (Sokal and Rohlf 1981) on median values of woodlot variables show percent agriculture and number of isolated woods are significantly different at ($p = .05$) for the two landscapes. The rest of the variables are not significantly different an inference that differences between the two landscapes may not be clear at the patch scale. However, the findings validate to some extent the treatment of Arnprior as a more intense agriculture landscape and Renfrew as a less intense agriculture landscape. Further to this, the findings provide a basis for performing a factor analysis on the woodlot variables in order to relate woodlot factors to landscape patterns.

Thematic Mapper Image "Groundtruth"

Woods appears red on false colour thematic mapper image (Table 5) due to its spectral reflectance in the near infrared band (Greegor 1986, Naveh and Lieberman 1984, Lillesand and Kiefer 1979). Water is black because it absorbs most of the incoming radiation. Bare surfaces, residential areas and recently ploughed fields with crops spaced like corn (newly planted) reflect a lot of incoming radiation in the blue wavelength. Crops with a prostrate growth like legumes will reflect almost like woods in the near infrared. Pasture, hay and corn (mature) absorb and reflect incoming radiation almost equally in the visible spectrum and will tend to have a mixture of colours which may show as white on the image.

Table 5. "Groundtruthing" Thematic mapper image false colours.

Thematic mapper false colour	"Groundtruth"
-----	-----
Near red to deep red	Wood
Black	Water
Near black /red	Swamp/Wood
Deep blue	Bare surfaces/ Residential/and Ploughed fields
Blue /black	Swampy/Rocky ground
Near white/light blue	Pasture
Near white/light red	Hay/corn (mature)
Light/deep purple	Legumes

Landscape Classification

Landscape classification (Table 6) reveals that 67% of the Arnprior landscape is devoted to agriculture which includes land uses such as corn, small grain, and hay. Woods occupy 19% of the landscape. The amount of corn and small grain grown in Arnprior landscape is more than double that of Renfrew landscape. Hay production in Arnprior is almost a half that grown in Renfrew landscape. Wild habitats, marshes and swamps are lower in Arnprior than in Renfrew. In the Renfrew landscape, 50% is devoted to agricultural land uses. Wood coverage is higher (30%) than Arnprior. Renfrew landscape shows an opposite trend with respect to patterns of land use compared to Arnprior landscape. There are lower amounts of corn and small grain production. The amount of hay, wild habitat, marshes and swamps are more in Renfrew landscape than in Arnprior landscape. Agriculture and residential occupy 69% of Arnprior landscape while 51% is in Renfrew landscape. These results further validate the treatment of Arnprior as a landscape subject to more intense agriculture and Renfrew as less intense agriculture. Landscape variables (Table 7) show more agriculture and isolation of woods in the Arnprior landscape. In contrast, the Renfrew landscape shows more wooded area with less isolation of individual woodlots by intervening croplands.

Table 6. Landscape classification of Arnprior and Renfrew landscapes.

Landscape	Area (hạ)	Percent cover							
		Co	Sg	Ha	Wo	Wh	Ms	Wa	Re
Arnprior	45000	34	15	18	19	7	4	1	2
Renfrew	40000	16	6	28	30	11	7	2	1

Co=Corn, Sg=Small grain, Ha=Hay, Wo=Wood, Wh=Wild habitat,
Ms=Marshes and swamps, Wa=Water and Re=Residential.

Table 7. Landscape variables measured from Thematic mapper image.

Variables	Landscapes	
	Arnprior	Renfrew
<hr/>		
Extensive Agriculture		
Longest axis	38	15
Percent cover	57	36
Perimeter	100	67
Interior index	8125	4375
Extensive woods		
Longest axis	21	15
Percent cover	11	22
Perimeter	55	71
Interior index	1406	2188
Distance	16	3
Number of isolated woods	54	17
Total percent cover of woods	19	30
Total percent cover of agriculture	67	50
<hr/>		

Data Analysis

Factor analysis

There is a high significant correlation ($p < .01$), (Table 8) between longest axis of a woodlot and perimeter, log area and log interior index. Arcsine percent agriculture shows significant negative correlation ($p < .05$) between longest axis and perimeter. Factor extraction (Table 9) shows that 3 factors account for 75.3 % of the total variation in the data set. Factor 1 accounts for 41.8 % while Factor 2 accounts for 22.4 % and Factor 3 for 11.0 % . Half of the communalities are close to .900 indicating that all the variance in the data set is explained by the common factors (Norusis 1985). Communalities can range from 0 to 1, with 0 indicating that the common factors explain none of the variance, and 1 indicating that all the variance is explained by the common factors. The factor matrix (Table 10) shows factor 1 having high factor loadings ($> .850$) only for number of hedges (HEDG) but shows important factor loadings for : longest axis (LGAX), length of hedges (LHEDG), log area (LAREA) and log interior index (LINTDEX) which indicates close relationship with these variables. Factor 2 has strong relationships with longest axis and perimeter of woods (PRMWL) and some relationship with log area and log interior index. Factor 3 has its most important relationship with arcsine percent agriculture (TAGR) and number of isolated woods (ISWL).

Table 8. Factor analysis correlation matrix of woodlot
variables.

	LGAX	PRMWL	ISLWL	INDSTNWL	HEDG	LHEDG	TAGR	LAREA	LINTDE
LGAX	1.000								
PRMWL	.956**	1.000							
ISLWL	.566*	.450*	1.000						
INDSTNWL	-.196	-.001	-.105	1.000					
HEDG	.587**	.475*	.416*	-.293	1.000				
LHEDG	.576**	.525*	.135	-.080	.676**	1.000			
TAGR	-.459*	-.463*	.172	-.014	-.216	-.409	1.000		
LAREA	.938**	.902**	.595*	-.177	.694**	.606**	-.321	1.000	
LINTDEX	.866**	.839**	.625*	.004	.648**	.557*	-.203	.907**	1.000

* $p \leq .05$ ** $p \leq .01$

Table 9. Factor extraction.

FACTOR	EIGEN VALUE	PCT OF VAR	CUM PCT
1	3.763	41.8	41.8
2	2.020	22.4	64.3
3	0.992	11.0	75.3

VARIABLE	COMMUNALITY
LGAX	.969
PRMWL	.962
ISWL	.645
INDSTNWL	.088
HEDG	.997
LHEDG	.577
TAGR	.717
LAREA	.952
LINTDEX	.870

Table 10. Factor matrix.

	FACTOR 1	FACTOR 2	FACTOR 3
LGAX	.683*	.709*	-.023
PRMWL	.581*	.787*	-.068
ISWL	.463	.320	.573*
INDSTNWL	-.286	.070	.028
HEDG	.990*	-.127	-.003
LHEDG	.699*	.137	-.262
TAGR	-.260	-.350	.726*
LAREA	.776*	.582*	.107
LINTDEX	.724*	.543*	.225

* factor loadings >.500 (Norusis 1985)

Multiple Regression of Breeding Bird Species
Numbers against Woodlot factor scores

In order to validate the ecological significance of woodlot factors, I performed a multiple regression of breeding bird species numbers against woodlot factor scores (Table 11). Multiple linear regression analysis uses a linear model that relates a dependent variable to a set of independent variables (Norusis 1985). The goodness of fit of the linear model is shown by the R^2 coefficient. If all observations fall on the regression line, R^2 is 1 and if no linear relationship exists between the dependent and independent variables, R^2 is 0. I report results from backward elimination (Norusis 1985) whereby it started with all variables in the linear model equation and sequentially removed them. The removal criterion is based on the minimum F-value a variable must have in order to remain in the equation. (Other methods were tried but offered no clear advantage.)

Results on multiple regression of breeding bird species against woodlot factor scores (Table 11) and (Table 12) shows the slopes to be higher for the Renfrew landscape than the Arnprior landscape. Factor scores 2 and 3 have the higher slopes in the Renfrew landscape by either analysis (with or without factor 1). In the Renfrew landscape, 3 factors account for 86% of the total variation

in the number of breeding bird species. Factor 2 and 3 alone account for 75%. In the Arnprior landscape, 96% of the variation in the number of breeding bird species is accounted for by 3 factors and 92% by factors 1 and 2 alone.

First factor analysis had entered distance to nearest woodlot (DSTNWL) as the direct measures in metres. Because this measurement is associated with several variables intended to measure lack of fragmentation, (DSTNWL) was re-entered as the reciprocal of the distance in metres. Re-analysis this way gave out 3 factors and the amount of variation accounted for increased. Inverse distance to nearest woodlot (INDSTNWL) was insignificantly correlated (.2) to variables relating to size of fragments. However, this change resulted in new interactions among variables, factor loadings and regression relationship of factors against breeding bird species numbers. Factor analysis appears to be sensitive on methods of measuring variables especially small nonlinearity in DSTNWL changed to INDSTNWL results in large changes due to changed variable interactions. Major variables involved appear the same after re-analysis except that the importance of hedgerows is greater. This findings cautions the nature with which variables must be entered during the analysis.

Table 11. Breeding bird species and woodlot factor scores

used in multiple regression .

Landscape	Woodlot Area	Factor score 1	Factor score 2	Factor score 3	Bird * species
Arnprior	4	-1.00	.05	-.34	19
	5	-.90	.01	-.31	22
	8	-.94	-.65	.04	20
	13	.19	-1.03	-.95	24
	16	.35	-1.09	-.96	25
	44	.79	.09	-.94	27
	58	1.81	-1.01	-.08	27
	220	1.13	2.63	-.85	31
Renfrew	3	-1.15	-.60	.42	17
	7	-.41	-.84	-.44	17
	8	-.79	-.05	.27	16
	14	-.94	1.35	.07	25
	17	-.26	.42	.25	26
	38	-.07	1.04	-.01	33
	54	.44	.08	2.52	41
	175	1.76	.37	1.30	31

* Bird data provided, courtesy of Dr.K.Freemark (Canadian Wildlife Service, Environment Canada, Ottawa).

Table 12. Multiple regression of breeding bird species
against woodlot factor scores.

Landscape Variable		Y-Intercept	Slope	sig.	F-value	R ²
Renfrew	Factor score 3	22.79	5.25	.072	8.39*	.86
	Factor score 2		6.02	.051		
	Factor score 1		3.88	.150		
	Factor score 3	20.96	7.44	.017	7.67*	.75
	Factor score 2		5.55	.085		
	Factor score 1					
Arnprior	Factor score 3	22.96	-1.89	.150	29.44*	.96
	Factor score 2		1.12	.033		
	Factor score 1		2.92	.002		
	Factor score 2	23.97	1.24	.030	29.69*	.92
	Factor score 1		3.14	.001		
	Factor score 3					

* $p \leq .05$

DISCUSSION

Relating Woodlot Factors to Landscape Pattern

Based on the variables most strongly associated with the factors, factor 1 could be interpreted to represent a situation with little forest fragmentation. Factor 2 could represent an intermediate situation where forests are still large but elongated or irregular in shape (such as along valleys). Factor 3 relates strongly only to two variables; amount of agriculture, and number of isolated woods. This could represent extreme fragmentation by intense agriculture.

In order to relate woodlot properties to landscape pattern, I identified landscape variables (Table 7) which indexed the amount of agriculture, woods and degree of isolation in Arnprior and Renfrew landscapes. These variables denoted the major differences between the two landscapes and reflected woodlot factors at the landscape scale. Table 7 shows that Arnprior has a high human activity and low woody cover as measured by variables indicating amount of agriculture, woods and degree of isolation. The converse is true for Renfrew landscape, a low human activity and a higher wood coverage. This is corroborated by the landscape classification for these areas (Table 6). If human activity is measured as the total amount of agricultural cropland and residential area, it is 69% for Arnprior landscape while

Renfrew is 51%. On the other hand, the amount of wood cover in Renfrew is 30% while in Arnprior is 19%.

Landscape classification further reveals that the Arnprior landscape concentrates more on agricultural cash crops such as corn and small grains (oats, barley and wheat). In the Arnprior landscape, the amount of hay, wood, wild habitat, marshes and swamps is lower than in Renfrew due to intensification of cash crop production. In contrast, Renfrew landscape shows more hay and less than half as much corn and small grain production compared to the Arnprior landscape. This is an indication of lower agricultural intensity in Renfrew. This difference is further evidenced by the amount of woods, wild habitat, marshes and swamps coverage. In summary, the Arnprior landscape has more human activity and low amounts of wood cover with few interconnections while Renfrew landscape shows less human activity, more wood, and more interconnections consistent with Freemark and Merriam (1986) study in Arnprior landscape and my observation from thematic mapper image.

My study on patches and landscapes enables me to highlight some points which may contribute to existing landscape ecological knowledge. Firstly, according to my view a landscape fits this definition, "a heterogeneous land area consisting of patches". Patches appeared to me spatially well defined while landscapes depended on one's

categorisation and study interests. Secondly, I disagree with Forman and Godron (1986) in that a landscape need not have a cluster of ecosystems repeated, nor their size limited down to a few kilometres in diameter and the matrix may be extensive but not necessarily continuous. Thirdly, as regarding the ecotope concept and its allied holistic concept where landscapes are delineated on the basis of soil, vegetation and faunal attributes (Thie and Ironside 1976, Zonneveld 1979, Naveh and Lieberman 1984), I support strongly the patch concept (Merriam 1984 and Opdam 1984) which relates better to animal groups than soil and vegetation classification maps.

The Ecological significance of Woodlot Factors

Through Factor analysis and landscape classification, I have established that Arnprior and Renfrew landscapes differ in amounts of agriculture, wood and degree of isolation. Woodlot variables were relatable to landscape patterns. Given this relationship, if woodlot variables can be shown to have ecological significance, then possibly future ecological landscape planning can be based on landscape variables without always having data from individual patches. Opdam (1984) points out that the distribution of many bird species is more or less unstable especially during migration but in the reproductive season breeding birds are restricted to their territories. Their distribution remain constant and therefore breeding bird species are suited to study relations of animals to vegetation patches (see also Freemark and Merriam 1986).

To relate breeding bird species to wooded patches, I performed a multiple regression of breeding bird species numbers as a dependent variable against woodlot factor scores as independent variables (Table 11). These woodlot factor scores may be interpretable as ratings on lack of fragmentation (factor score 1), woodlot shape and size (factor score 2) and agricultural intensity and resultant isolation of woods (factor score 3).

Relationships of these factors to breeding diversity of woodland birds can be interpreted from significance levels of the regressions of the factor scores against bird species numbers. In the Renfrew landscape, factor 1 (lack of fragmentation) is not significantly related (.15) to bird numbers probably because this factor does not vary greatly among the woods analysed. Factor 3 also is marginally insignificant (.07) in Renfrew probably because intense agriculture and isolation of woods was uncommon. However, when factor 1 is eliminated, factors 2 and 3 explain 75% of the variance in bird numbers in this landscape. The higher slopes in Renfrew landscape may suggest that breeding bird species tend to accumulate faster due to availability of colonisers from its large woods.

In the Arnprior landscape, factor 3 (extreme fragmentation) shows a negative relationship to bird numbers but it is not significant (.15). Factors 1 and 2 alone explain 92% of the variation in bird numbers. Their highly significant relationships (.01, .03) is probably related to the importance of lack of fragmentation (factor 1) and the commonness of intermediate levels of fragmentation and associated reshaping of remaining woods. The higher R^2 value for Arnprior landscape which has lower amount of wood cover compared to Renfrew may indicate that bird species make fuller use of small woodlots in this

landscape than in Renfrew landscape where there are alternatives for larger woodlots.

Freemark (unpublished), Freemark and Merriam (1986) reporting on a study in these landscapes found that larger forests supported more bird species than smaller forests in both landscapes. However, few forest interior species occurred in smaller forests in both landscapes. They further found that patterns in bird species numbers differed between landscapes primarily because of differences among some ecological classes of birds. Forest interior species and species with larger territories were common in the landscape which appeared more forested and more interconnected (Renfrew) than in the less forested and less interconnected landscape (Arprior).

Distance to nearest woodlot may also determine bird species dispersal and hostility of interpatch habitat which may cause extinctions of species. Opdam et al. 1984 point out that in spite of the flying abilities of forest birds, even a small gap of open land may lower the immigration rates of several species of birds. Area which is closely related to interior index, longest axis and perimeter has for a long time been related to species richness (MacArthur and Wilson 1967, Whitcomb et al. 1977, Burgess and Sharpe 1981, Freemark and Merriam 1986 among others). The main argument is that bigger forested areas have greater habitat heterogeneity and hence offer more habitats for species. Bigger forested areas

have higher recolonisation rates and lower extinction rates as compared to smaller forested areas. Furthermore, bigger interior indexes of wooded patches help in supporting more ecological classes of birds especially forest-interior species, species with larger territories, and long distance migrants (Freemark and Merriam 1986). The overall effect of area and its closely related variables appears to be increasing species richness of wooded patches. The number of hedgerows and hedgerow length have been found to significantly increase the number of bird species in some agricultural landscapes (see Osborne 1984 and Arnold 1983). Besides this, hedgerows have an important ecological function of dispersing flora and fauna especially in heavily fragmented woodlands (Wegner and Merriam 1979).

Human activity is related to amount of agriculture and number of isolated woods in the landscape. Besides these variables, this factor may be felt through farm buildings, roads, power lines, domestic animals and activities of inhabitants (see Mader 1984 and Zande et al. 1980). Road construction and agricultural activities contribute to habitat isolation and habitat loss which have far-reaching effects on species. Field studies have suggested that roads represent barriers and cut off the gene flow by dividing animal populations into fractions on either side of the road (Mader 1984 and Merriam 1984 among others). Populations living in fragmented habitats will be more

prone to extinctions and will have low recolonisation rates due to isolation effects. Woodlots in heavily humanised landscapes will have small areas and low interior indexes which may not support all ecological classes of birds (Freemark and Merriam 1986). In principle, the fragmentation of habitats due to human activities in the landscape may result in habitat loss and isolation thereby introducing insular and genetic effects (Soule'1986) which causes extinction of species. These arguments support the widely held view that human activity may be associated with low species richness.

The outcome of these multiple regressions is not at variance with facts in literature about some of the factors determining breeding bird species richness in fragmented woodlots. Bird species richness in woods may be governed by internal as well as external factors. Internal factors are habitat variables and size. Among external factors are features of the surrounding landscape(e.g. availability of feeding sites and geographical position of the forest island in relation to other woods of the same type (Opdam 1984, Freemark and Merriam 1986). Bird species richness has been found to be correlated with habitat island area, (Whitcomb et al. 1976, Forman et al. 1976, Lussenhop 1977 and Robbins 1979). Opdam et al.(1985, 1984) working on some fragmented woodlots in a Dutch agricultural landscape found that woodlot area, distance to nearest

large forest and amount of wood near the forest island were significantly correlated with bird species numbers. The species showing effect of isolation were both sedentary and migratory. Further to this Whitcomb et al. (1981) found isolation to have an effect on the number of forest interior birds in small fragmented woodlots. Galli et al. (1976) indicated that very small woods (<1ha) contained only bird species characteristic of forest edges. Birds characteristic of forest interior began appearing in islands greater than 1 hectare. Howe (1979) showed that very small islands satisfy the requirements of only a few species that favour edge or open habitats, and perhaps also those with very generalised foraging preferences (see also Freemark and Merriam 1986). Lynch and Whigham (1984) in their study based on 270 forest patches found breeding bird species significantly influenced by forest area, isolation, structure or floristics or a combination of these factors. Their findings further indicate that even a slight degree of habitat isolation importantly reduces the abundance of some migratory species in forest patches. Whitcomb et al. (1981) showed that fairly small forest patches can maintain a reasonably complete avifauna provided their isolation from the nearest extensive "mainland" source area is sufficiently low. Butcher et al. (1981) studied breeding bird species turnovers as related to changes in vegetation and urbanisation on an upland site in Connecticut. They

found that turnover of breeding bird species on an old field portion of the site was due to vegetation changes that caused the extinction of species preferring open shrub habitats and the colonization of species preferring forest. Turnover of breeding birds on the forest portion was due to its increasing isolation from similar forest habitat, resulting in the local extinctions of forest interior species and the colonization of species characteristic of suburban habitats. Soule'and Wilcox (1980) summarise the effect of habitat fragmentation as consisting of two aspects:habitat loss and insularization. Each contributes to the number of species supported although different mechanisms are involved. Habitat loss contributes by excluding a portion of the fauna particularly the rare species and by increasing extinction rate of the remaining species as a result of lower population size. Habitat insularization contributes by extinguishing species "protected" within an area through removal of required resources outside the area and by reducing sources of colonists necessary to offset extinction. Such a situation may be the one now operating in the Arnprior and Renfrew landscapes which are experiencing different intensities of human use.

Natural Resource Management Options

There is a lot of debate about the best ways of conserving natural resources in human dominated landscapes. There are some who advocate maintenance of large reserves or forest areas greater than 100 hectares (Helliwell 1976, Moore and Hooper 1975, Forman et al. 1976, Whitcomb et al. 1977, Freemark and Merriam 1986) specifically for avifauna conservation. Isolation has been found to have a long term effect on animal populations (Mader 1984, Wegner and Merriam 1979, Noss 1983, MacIntock et al. 1977) due to cutting off the gene flow by dividing populations into fractions. Populations living in fragmented habitats will be more prone to extinction and will have low recolonisation rates due to isolation effects. These authors have suggested provision of vegetated corridors to relieve the barrier effects. In order to minimise isolation, park planners are advised to connect significant patches of habitat with another park (Noss 1983, MacIntock 1977).

Maintenance of more edge (Leopold 1933, Forman and Godron 1986) has always been a management tool to encourage more species diversity. However, a more advanced conservation management guideline suggests maintaining landscape heterogeneity. This has come up by the realisation that many animals require two or more landscape

elements to survive (Forman and Godron 1986, Freemark and Merriam 1986, Stenseth 1980 and Hansson 1977) and for other reasons too (see Middleton and Merriam 1985, Soule' and Wilcox 1980 and Soule' 1986). Wiens and Dyer (1975) working in North America found that unbroken monocultural crop fields (consisting of alfalfa, corn and wheat) had lower avian breeding densities and species diversity compared to more broken fields (consisting of fallow, hay, pastures and wood). This heterogeneity they argue would promote more species diversity in a landscape. Karr (1982a & b), Karr and Freemark (1983) have noted that even in continuous forest, bird species require a mosaic of habitat patches. Further to this, Pickett and Thompson (1978) suggest that reserves should be designed and managed so that maximum number of successional stages are repeated. They contend that within-reserve heterogeneity maximises species diversity. Stenseth (1980) has empirical evidence for some taxa that heterogeneous environments will have more species than homogeneous ones. Noss (1983) sums up by highlighting that long term maintenance of diversity requires a management strategy that considers regional biogeography and landscape pattern above local concerns (see Middleton and Merriam 1985 also).

Conservation of large mammal species requires an intensive management programme because mammals are more vulnerable to extinction than birds (Soule' and Wilcox

1980). It is true that boundaries of game reserves will rarely coincide with those of ecological systems and the requirements of a species may not be met within the reserve. A good example is the migrating herds of wildebeest, zebra and elephants movements in African game reserves. As long as the habitat adjacent to the reserve persists, the wildlife will exist. However, if the neighbouring habitat is removed for agriculture and other land uses, these animals will disappear unless intensively managed (Soule'1986, Soule'and Wilcox 1980). Soule'(1986) points out that some fragments created by human land uses are smaller than the minimum home ranges or territories of some species especially the large mammals. He further argues that the landscape created by man is a formidable barrier to colonists from fragments. Furthermore, this human dominated landscape can contribute directly to the extinction of species in fragments. It does so by building populations of animals that are harmful to species within fragments. Noss (1983) notes that the rare species are most vulnerable to extinction and must receive the greatest attention, (see also I.U.C.N. 1980).

The retention and preservation of presettlement ecosystems especially old forest stands with native species is highly recommended for perpetuating biotic diversity (I.U.C.N. 1980, Soule'and Wilcox 1980, Noss 1983, Middleton and Merriam 1985, Soule'1986). The principles of habitat

fragmentation and insularization effects holds true for forested ecosystems. The rare species are more vulnerable to extinction and require the greatest attention along with species whose medicinal value is unknown.

From the foregoing, it is clear that resources in man-dominated landscapes require an ecologically sound land use plan. The greatest threat of Human activities as regards animals and plants is habitat fragmentation which has two components: habitat loss, and insularization (Soule'1986). These components affect animals and plants through extinctions of species as a result of habitat destruction and genetic effects. A sound land use plan using landscape ecological knowledge is urgent if the remaining resources are to be preserved and and utilised on a long term basis. This land use management plan must be based on ecological principles that emphasize the use of our remaining resources on a sustainable yield basis. These may call for revised land uses (especially in retrievable lands) in which new land uses are allocated on land capability and landscape ecological considerations (see I.U.C.N. 1980). For example, agricultural production should be allocated on lands capable of sustaining agriculture. Agriculture is a form of human disturbance and if allocated to non sustainable lands it may leave the land unproductive forever. Fragile lands especially semi- and arid lands of Africa must have proper stocking rates for both wildlife

and livestock. Excess numbers of wildlife and livestock destroy both herbage and other woody elements which may lower species diversity as evidenced in this study.

Creation of buffer zones around game reserves to prevent human impacts and rehabilitation of already degraded lands is recommended in order to minimise human disturbance in landscapes. Buffer zones around game reserves may act as stepping stones to dispersing animals. Further to this, buffer zones insulate animals from human disturbance which was found to affect species richness. Uncompatible land uses such as mining should not be located near wildlife areas to prevent further wildlife loss. Mining is one form of human disturbance which destroys habitat and isolates plant and animal communities. Mineral prospecting should be carried out in areas where it will have minimal effects on wildlife. Likewise, development projects which are also a kind of disturbance as they destroy and isolate habitats should be allocated on poor quality lands away from nature reserves. Agroforestry incorporation into cropland and pastureland would ensure sources of food and fuel for subsistence farmers especially in developing nations. Rather than having extensive agricultural fields, maintaining mosaics of woods, wild habitat, pasture and crops may promote species richness as found in this study. Besides this, such elements of vegetation can control environmental degradation especially soil erosion.

In summary, an ecologically sound land-use plan that considers the effects of habitat loss and insularization would be best for conservation of plants and animals. Landscape variables can be quantified using remote sensing tools such as Landsat imageries which was useful in this study. These landscape variables can reveal the regional habitat mosaics which can be the basis of ecological land-use planning. Further to this, habitats could be monitored on given spatial and temporal scales to assess disturbance on landscapes. This assessment can guide on action to be taken to prevent further habitat loss and fragmentation.

CONCLUSIONS

1. Wooded patch properties were related to landscape patterns.
2. Breeding bird species numbers were directly related to ecological properties of wooded patches and therefore, breeding birds species were related to landscape patterns.
3. Woodlot shape, size and degree of isolation in a landscape accounted for most of the variation in breeding bird species numbers.

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