Landscape Ecology vol. 7 no. 4 pp 275-289 (1992)
SPB Academic Publishing bv, The Hague

Land use dynamics within an urbanizing non-metropolitan county in New York State (USA)

James A. LaGro Jr.[1] and Stephen D. DeGloria[2]
[1] *Department of Landscape Architecture, 25 Agriculture Hall, University of Wisconsin-Madison, Madison, Wisconsin 53706, USA;* [2] *Department of Soil, Crop, and Atmospheric Sciences, 453 Hollister Hall, Cornell University, Ithaca, New York 14853, USA*

Abstract

Land use/land cover data for fifteen minor civil divisions (MCDs) in Ulster County, New York (USA) were interpreted from 1968 and 1985 aerial photographs. These data were combined with ancillary physiographic and demographic data as raster layers within a computerized geographic information system (GIS). Class to class changes in land use/land cover were quantified for a study area approximately 30 kilometers by 50 kilometers. The relationships between the land use/land cover variables and the ancillary variables were modeled in a series of weighted least squares regressions employing data spatially aggregated by general soil map unit (N = 44).

Between 1968 and 1985, nearly one-third of the study area changed to another land use/land cover class. Land in the urban class increased from 6.7% to 17.8% of the study area, while the forest class declined from 65.0% to 55.2%, and the agriculture class declined from 12.7% to 8.9%. Gains and losses in the remaining five major (Level I) land use/land cover classes were relatively small. Land use changes primarily involved the conversion of land from the forest, agriculture, and vacant classes to the urban class, and from the agriculture class to the forest and vacant classes. Variables accounting for the variance in the land use/land cover class proportions of the soil units were population density, highway proximity, distance to urban centers, mean elevation, mean slope gradient, and soil suitability for farming and for urban development.

1. Introduction

Human population growth and redistribution have precipitated the conversion of substantial areas of land in the United States from rural to urban uses (Zeimetz *et al.* 1976; Vesterby and Heimlich 1991). Preferences for residential locations in suburbs, small cities, and rural areas have contributed to the deconcentration of population from large urban centers during the past two decades (Wardwell 1980; Zuiches 1981; Fuguitt and Brown 1991). Comparatively low rural land costs, high rural amenity values, and unprecedented human mobility have made many rural areas both feasible and attractive locations for extensive residential development. The weakening 'friction of distance' has thus exacerbated the effect of population growth in precipitating landscape change within the United States.

Multivariate analyses of landscape change increasingly employ geographic information systems (GISs) to integrate land use/land cover data with other ancillary demographic and physiographic spatial data. In a study of urbanized land within the townships of two counties in New Hampshire, for example, Befort *et al.* (1988) regressed the town-

ships' developed land area in 1982 on the following township variables: developed land area in 1953, township area, absence/presence of an interstate highway, distance to the nearest urban center, and township population in 1950. In a study of Illinois, Iverson (1989) utilized the soil association as the unit of analysis, and employed the percentages of the soil associations attributable to each land use/land cover class as dependent variables. Percentages for each of the twelve classes were regressed on several weighted soil association attributes. In spite of the growing attention given to landscape change, the land use changes resulting from human population growth and redistribution, and the ecological effects of these land use changes, remain poorly documented.

This paper presents the findings of research on land use change within an urbanizing non-metropolitan county in southeastern New York State (USA). The major objectives of this study were to: 1) document the land use dynamics occurring between 1968 and 1985 within the county that, over this period, was adjacent to two Standard Metropolitan Statistical Areas (SMSAs); and 2) examine the relationships in the county between land use/land cover spatio-temporal patterns and several physiographic and demographic factors.

2. Methods

2.1. Study area

The study area is comprised of fifteen minor civil divisions in Ulster County, a non-metropolitan county in the mid-Hudson River Valley of New York State (Fig. 1). The county is located within 170 kilometers of five Metropolitan Statistical Areas (MSAs), which are former SMSAs, and is adjacent to two of these five. The study area is accessible by motor vehicle from the adjacent Poughkeepsie MSA to the east, via three two-lane bridges over the Hudson River, and from the adjacent Orange County MSA to the south, via several heavy- and medium-duty highways. Limited-access interstate highways also link the study area to the New York MSA and the Binghamton MSA via US Route 17, and to the Albany-Schenectady-Troy MSA via US Route 87.

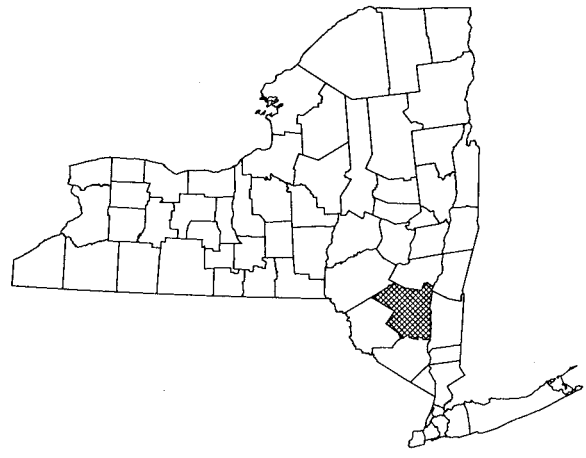

Fig. 1. Location of Ulster County in New York State (USA).

2.2. Assembling the spatial database

A commercially available image processing (IP) and geographic information system (GIS) software package (ERDAS, Inc. 1988), operating on an IBM AT personal computer, was employed to organize, store, and process the spatial data utilized in this study. The primary unit of analysis was the general soil map unit, a spatial entity with cartographic and taxonomic detail that is intermediate between a soil association map unit and a detailed county soil series map unit (US Department of Agriculture 1977). Regression analysis, correlation analysis, and other statistical analyses completed in this study were facilitated by integrating remote sensing data and other ancillary spatial data in a computer-based raster GIS. The variables employed in the correlation and regression analyses were land use/land cover, human population density, distance from urban centers, highway proximity, mean elevation, mean slope gradient, and soil suitability for urban development and for farming.

2.2.1. Land use/land cover

Two sets of land use/land cover data for fifteen minor civil divisions in the county were digitized from hand-drawn maps. The fist set of 1:24,000-

scale New York State Land Use and Natural Resource Inventory (LUNR) maps consisted of mylar overlays compiled from data interpreted from 1:24,000-scale panchromatic aerial photographs taken in April 1968. Each LUNR map overlay corresponds to a USGS 1:24,000-scale topographic map. A total of twenty-four partial and complete quadrangle maps were utilized in this study.

The second set of land use/land cover maps, nominally for the year 1985, were derived from the interpretation of 1:58,000-scale color infrared National High Altitude Photography (NHAP) taken primarily in April 1985, and also in July 1984 and April 1986. These maps were published in 1988 for the Ulster County Department of Planning by the Resource Inventory Program of the Cornell Laboratory for Environmental Applications of Remote Sensing (CLEARS). Interpretations were delineated on mylar overlays using a 2–4× power stereoscope, and optically transferred to 1:36,000 scale mylar base maps using a Bausch and Lomb zoom-transfer scope.

Although the scale of the 1968 photographs differed from the scale of the 1985 photographs, the ground resolution of each set of photographs was relatively high. Large- to medium-scale (1:10,000–1:60,000) aerial photographs have image resolutions of about 20–30 line pairs per millimeter for low contrast objects, and thus ground resolutions of 0.3 to 3.0 meters. Each set, therefore, was suitable for delineating land use and land cover classes as detailed as US Geological Survey (USGS) Level III categories (Jensen 1983).

The minimum mapping unit for both the 1968 and 1985 maps was approximately one acre (0.39 hectares) (New York State Office of Planning Coordination 1971; Ingram 1989, personal communication). Because the land use/land cover classification systems utilized in mapping the 1968 and 1985 data were hybrid systems, created by combining USGS Level II and III categories (Anderson *et al.* 1976), the land use/land cover data from each map set were manually digitized and electronically aggregated in this study to produce a single, comparable twelve-class system for both data sets (Table 1). Although limited access highways were included in the urban (transportation and communication) class, other rural roads and highways were included within adjacent urban and non-urban classes.

Table 1. Ulster County study area land use/land cover classification system.

Urban
Residential
Commercial
Industrial
Transportation and Communication
Public
Mines, Quarries, and Gravel Pits
Outdoor Recreation
Agriculture
Vacant, Barren, or Transitional
Forest
Wetland
Water

Both sets of digitized land use/land cover vector data were converted to digital grid-cell images having effective cell sizes of twenty-five meters square (0.0625 hectares). The fifteen minor civil division boundaries were manually digitized from USGS 1:24,000-scale topographic maps, and the land use/land cover digital maps were electronically segregated with each appropriate minor civil division boundary vector file. The land use/land cover digital maps for all fifteen MCDs were then placed into a composite file encompassing the entire study area. The study area comprised 2,425,256 grid-cells, and represented a surface area of 1517.5 square kilometers (585.2 square miles).

Soil map unit boundaries were manually digitized from a 1:62,500-scale general soil map published by the USDA Soil Conservation Service (US Department of Agriculture 1977). The Hudson River and other large water bodies within the fifteen MCD study area were encoded as unclassified areas within this data layer. To reduce displacement error, multiple map set-ups were used to incrementally digitize and geo-reference the map. In each map set-up, a land surface area of approximately 100 square kilometers was digitized and georeferenced. The land use/land cover area within each soil unit was quantified by comparing the digital land use/land cover maps with the digital general soil map. These areas were converted to proportions, and the

changes in both areas and proportions were computed for each class within each soil unit in the study area (LaGro 1991). The study area encompasses 44 of the 45 general soil units occurring within Ulster County (Table 2).

2.2.2. Human population density

The population of each MCD in 1968 was estimated by linear interpolation from 1960 and 1970 census data (US Bureau of the Census 1982). Population data for 1985 were interpolated from inter-censal population estimates for 1984 and 1986 (US Bureau of the Census 1988). The population density of each soil unit was a weighted estimate derived by the following algorithm:

$$\sum_{i=1}^{n} \frac{P_i D_i}{A_i} \qquad (1)$$

P_i = proportion of the soil unit area within MCD i
D_i = population of MCD i
A_i = area of MCD i, in square kilometers

The 1985 population density and the change in population density between 1968 and 1985 are variables that were not included in the regressions using 1968 land use/land cover class data. In the regressions using 1985 land use/land cover class data, both 1968 and 1985 population density variables were included, in addition to the change in population density variable.

2.2.3. Distance from urban centers

Population deconcentration from New York State's urban centers has precipitated residential, commercial, and industrial development both in and beyond the state's rural-urban fringe. Distance from urban centers was utilized as an independent variable, therefore, in this study's series of regression analyses. The centers of all seven incorporated villages and cities in or near the study area were digitized from USGS 1:24,000-scale topographic maps. One kilometer-wide concentric rings, or annules, were generated around the digitized points representing the urban centers within Ulster County and two adjacent counties. Each ring was assigned a value equal to the distance from the outer limit of the ring to the urban center. The land area within each ring was computed and a weighted distance value was generated for each soil map unit. Although no attempt was made to weight the distances based on the magnitude of the proximate urban populations, the approach adopted here does provide a coarse indicator of potential population redistribution.

2.2.4. Highway proximity

Residential, commercial, and industrial activities within the study area typically require access to all-weather road systems. A hierarchy of roads exists within the study area:

- limited access, divided highways (usually 4 lanes)
- heavy-duty highways (usually 2 lanes)
- medium-duty highways (2 lanes)
- light duty highways (2 lanes)
- residential streets (2 lanes)
- unimproved, seasonal roads (2 lanes)

The heavy-duty, unlimited-access highways are state and county highways that were digitized from USGS 1:24,000-scale topographic maps, revised no later than 1970. These roads comprise a relatively small proportion of the all-weather roads within the study area. The measure of highway proximity utilized in this study was the proportion of each soil map unit occupied by a 1025 meter-wide corridor centered on the heavy-duty highways.

2.2.5. Elevation and slope gradient

Quantifying the mean elevation and the mean slope gradient of the soil units facilitated an assessment of the effect of landform on land use within the study area. These topographic data were obtained from USGS Digital Elevation Model (DEM) non-rectified data, having a grid-cell resolution of three arc-seconds by three arc-seconds of latitude and longitude (USGS 1987). At the latitude and longitude of this study area, a three arc-second grid-cell is equivalent to approximately 90 meters latitude and 56 meters longitude. The digital elevation data were rotated and rectified using a bilinear interpolation algorithm. This processing served to spatially reference the elevation layer to the other variables in the spatial database. One percent slope gradient intervals were computed from the elevation data

Table 2. General soil classification for Ulster County, New York.

Deep soils without fragipans formed in glacial till and in lacustrine mantled glacial till
1. Churchville-Madalin-Cayuga, gently sloping
2. Stockbridge-Farmington-Rock outcrop, rolling

Deep soils with fragipans formed in glacial till
3. Bath-Nassau-Mardin, rolling
4. Bath-Nassau-Rock outcrop, hilly
5. Lackawanna, very bouldery, moderately steep
6. Lackawanna, very bouldery, very steep
7. Lackawanna-Valois, very bouldery, steep
8. Mardin-Bath-Volusia, gently sloping
9. Mardin-Volusia-Bath, very stony, sloping
10. Scriba-Menlo, very bouldery, moderately sloping
11. Swartswood, very bouldery, moderately steep
12. Volusia-Lyons-Atherton, very stony, nearly level
13. Wellsboro, very bouldery, gently sloping
14. Wurtsboro, very bouldery, gently sloping

Moderately deep and shallow soils formed in glacial till over bedrock
15. Arnot-Lordstown-Rock outcrop, very steep
16. Arnot-Oquaga-Rock outcrop, very steep
17. Arnot-Rock outcrop, sloping
18. Arnot-Rock outcrop, moderately steep
19. Arnot-Rock outcrop, very steep
20. Farmington-Rock outcrop, steep
21. Lordstown-Arnot-Rock outcrop, gently sloping
22. Lordstown-Arnot-Rock outcrop, moderately steep
23. Lordstown-Mardin, gently sloping
24. Nassau-Bath-Rock outcrop, sloping
25. Nassau-Manlius, hilly
26. Oquaga-Arnot-Rock outcrop, sloping
27. Oquaga-Arnot-Rock outcrop, moderately steep

Deep soils formed in glaciolacustrine deposits
28. Hudson-Schoharie, steep
29. Raynham-Canandaigua, nearly level
30. Rhinebeck-Hudson, gently sloping
31. Rhinebeck-Madalin, nearly level
32. Schoharie-Odessa, sloping

Deep soils formed in glaciofluvial deposits
33. Hoosic-Chenango, gently sloping
34. Hoosic-Tunkhannock, rolling
35. Hoosic, steep
36. Hoosic-Red Hook-Castile, nearly level
37. Lamson-Pompton-Walpole, nearly level
38. Plainfield-Rock outcrop, rolling
39. Riverhead, nearly level
40. Tunkhannock-Suncook-Barbour, nearly level
41. Unadilla, nearly level

Deep soils formed in recent alluvial deposits
42. Hamlin-Haven-Wayland, nearly level
43. Tioga-Wayland-Middlebury, nearly level

Deep soils formed in organic deposits
44. Carlisle-Palms, level
45. Palms-Lyons, level

prior to rescaling these data into aggregated elevation classes of 50 meter intervals. The mid-point value of each elevation interval was the data value utilized in this study.

2.2.6. Soil suitability for urban development and for farming

The biophysical properties of soils present both opportunities and constraints for various land uses. Soil fertility and drainage influence the land's suitability for farming, for example, and depth to bedrock and strength are important factors in the construction of buildings, roads, bridges, and subsurface utility systems. Soil suitability ratings for farming and for urban development were derived from the Ulster County soil survey (US Department of Agriculture 1977), and were utilized in this study as independent variables. The soil ratings for farming suitability incorporate the effects of slope and elevation, in addition to the effects of soil texture, fertility, stoniness, and water holding capacity. The soil ratings for urban development incorporate the effects of slope, depth to bedrock, wetness, frost action, strength, stoniness, and flooding susceptibility.

The soil suitability ratings computed in this study for each soil unit were weighted values, based on the proportion of the total soil unit area occupied by each major soil series. Approximately 70% to 80% of each soil unit is comprised of two or more major soil series. Therefore, if three major soil series comprise 80% of the soil unit, the weighted suitability rating for that unit was computed using the suitability ratings for only those three major soil series.

2.3. Statistical analyses

2.3.1. Land use/land cover change analysis

Assessing land use/land cover change by electronically combining two separately generated digital maps can generate errors, or misclassified pixels, in the form of topological anomolies or 'slivers' (Jensen 1983). Although the sources of the land use/land cover data in this study were two separate maps, insights nonetheless were gained from a pixel by pixel comparison of the images. The land use/

land cover maps for 1968 and 1985 were compared to assess class-to-class transitions within the entire study area. The changes in five major (Level I) land use/land cover classes within each soil unit were also quantified.

2.3.2. Regression and correlation analyses

Five sets of multivariate regression equations were developed with data spatially aggregated by soil map unit. Five major (Level I) land use/land cover classes were selected as dependent variables because these were the largest classes by area within the study area, and because the land within each class was either predominantly or entirely under human influence. The five classes selected were the urban, forest, agriculture, vacant, and wetland classes. Land use/land cover class proportions for 1968 and 1985, and the changes in these proportions for each of the five classes, were the dependent variables (Y).

Because physiographic and demographic factors can act as both facilitating and constraining influences on land use/land cover patterns, several independent variables (X_i) were selected for their anticipated utility in accounting for variability in the proportions, and in the changes in proportions, of the soil units occupied by each of the five land use/land cover classes. The selection of the independent variables was influenced, in part, by the literature on the economics of urban amenities (Diamond and Tolley 1982; Knapp and Graves 1989), rural population growth (Fuguitt *et al.* 1979; Brown and Wardwell 1980; Fuguitt *et al.* 1989), and land use/land cover change in non-metropolitan counties (Platt and Macinko 1983; Befort *et al.* 1988).

Each linear regression model includes an error term (e) embodying errors attributable to measurement and sampling, to stochastic effects, and to effects of variables not included in the analysis (Equation 2).

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots + e \qquad (2)$$

Each soil unit was assumed to represent a relatively homogeneous area that individuals, in utilizing the landscape, could select from the complete population of soil units (N = 44). Both the independent and dependent variables were measured by averages, medians, or other descriptive statistics. The expected signs of the relationships between independent and dependent variables are listed in Table 3.

A logarithmic transformation was employed to reduce departures from normality for the following variables: 1968 and 1985 population density, mean distance from urban centers, mean elevation, mean slope gradient, and both farming suitability and urban suitability. To avoid potential problems associated with constrained error term variance for data values near the end points of the variable domain, the variance for the proportional data was stabilized with a logit transformation (Johnston 1984). Because several land use/land cover class proportions had the value of zero, one was added to each proportional ratio before computing the natural logarithm (Equation 3) (Snedecor and Cochran 1980).

$$\ln\left[\left[\frac{Y_i}{1-Y_i}\right] + 1\right] \qquad (3)$$

where Y_i = proportion of a soil unit in land use/land cover class i.

Changes in the class proportions of each soil unit were computed by subtracting the modified logit (Equation 3) of the 1968 proportion from the modified logit of the 1985 proportion.

Analysis of the residuals from preliminary unweighted regressions suggested that error term variance was high for soil units of small area, yet declined sharply as soil unit area increased. To reduce the influence of observations attributable to a few relatively small soil units, the observations were weighted by the area of each respective soil unit. The regressions were completed initially using the RSQUARE program in the SAS statistical analysis software package, a procedure similar to stepwise regression except that, in the RSQUARE procedure, the regressions are computed with all possible subsets of the independent variables (Freund and Littel 1986).

The model selection process begins by evaluating the full model, and then proceeds to the subset models containing progressively fewer independent variables. The selected model is the first subset model with a C(p) statistic that most closely ap-

Table 3. Expected signs of the relationships between dependent and independent variables in the regression analyses.

Independent variables	Dependent variables				
	Urban	Forest	Agriculture	Vacant	Wetland
	1968 and 1985 land use/land cover class proportions				
Slope Gradient	−	+	−	−	−
Elevation	−	+	−	−	−
Urban suitability	+	−	−	+	−
Farming suitability	−	−	+	−	−
Highway proximity	+	−	−	+	−
Distance from urban centers	−	+	+	−	+
Population density	+	−	−	+	−
	Change in land use/land cover class proportions				
Slope Gradient	−	−	+	−	+
Elevation	−	+	+	−	−
Urban suitability	+	−	−	+	−
Farming suitability	−	−	+	−	+
Highway proximity	+	−	−	+	+
Distance from urban centers	−	+	+	−	−
Population density	+	−	+	+	−

proaches p + 1 (Chatterjee and Price 1977; Freund and Littel 1986). The C(p) statistic proposed by Mallows (1973) is a measure of the total squared error for a subset regression model containing (p) independent variables. A complementary approach is to select the subset model showing a relatively wide divergence between the C(p) values of the best and second best equations for a given number of independent variables (Freund and Littel 1986).

Both of these variable selection techniques were employed to select between three and five subset models for each dependent variable. An F-test was employed to assess the overall model significance of the selected subsets by testing the null hypothesis that all parameter coefficients were zero. Student's t-tests were employed to test the null hypotheses that the individual parameter coefficients of the subset variables were zero. Evaluating the partial sums of squares from each regression permitted the systematic elimination of non-significant variables. Pearson product-moment correlation coefficients were also computed for all possible pairs of the dependent and independent variable data included in the regression analyses (Table 4).

3. Results and discussion

3.1. Land use/land cover dynamics

The results of the correlation and regression analyses suggest that several physiographic and demographic factors have influenced land use/land cover spatio-temporal patterns within the study area. Changes in significant variables and in coefficients of determination of the regression equations for a given dependent variable also suggest that changes occurred between 1968 and 1985 in the influence of physiographic and demographic factors on land use/land cover within the study area. Except for the vacant class and wetland class regression equations, all coefficients possessed the expected signs (Table 3).

Multicollinearity was assessed for each reduced model by regressing each independent variable on the remaining significant variables, and then evaluating the coefficient of determination (R2) for each equation to ensure that the coefficient did not approach 1.0 (Lewis-Beck 1980). Several interaction terms, comprising various combinations of independent variables, were also assessed. These two procedures produced little evidence of multicollinearity or significant interaction among the independent variables.

Table 4. Dependent and independent variable names and abbreviations.

Number	Abbreviation	Variable
1	68DENS	* 1968 population density
2	85DENS	* 1985 population density
3	DENSCHG	85DENS-68DENS
4	URBDIST	* distance from urban centers
5	URBSUIT	* urban suitability
6	FARMSUIT	* farming suitability
7	ELEV	* elevation (meters)
8	SLOPE	* slope (%)
9	ROADPROX	# proportion of unit in highway buffer
10	URB68	# 1968 urban proportion
11	URB85	# 1985 urban proportion
12	FOR68	# 1968 forest proportion
13	FOR85	# 1985 forest proportion
14	AGR68	# 1968 agriculture proportion
15	AGR85	# 1985 agriculture proportion
16	WET68	# 1968 wetland proportion
17	WET85	# 1985 wetland proportion
18	VAC68	# 1968 vacant proportion
19	VAC85	# 1985 vacant proportion
20	URBCHG	URB85-URB68
21	FORCHG	FOR85-FOR68
22	AGRCHG	AGR85-AGR68
23	WETCHG	WET85-WET68
24	VACCHG	VAC85-VAC68
25	AREA	* general soil unit area (km^2)

* logarithmic transformation; # logit transformation

Between 1968 and 1985, relatively small area increases occurred within both the quarries and mines class (0.3%) and the outdoor recreation class (0.2%), and a small decrease occurred in the area within the water class (0.1%) (Fig. 2). The largest losses were incurred by the forest and agriculture classes, while the largest gains occurred within the urban and vacant classes. Over this 17-year period, 67.9% of the study area remained in the same land use/land cover class, while 32.2% changed to one of seven other major land use/land cover classes (Table 5). Changes in the percentage of each soil unit occupied by the five major land use/land cover classes are listed in Table 6, and are discussed below for each individual class.

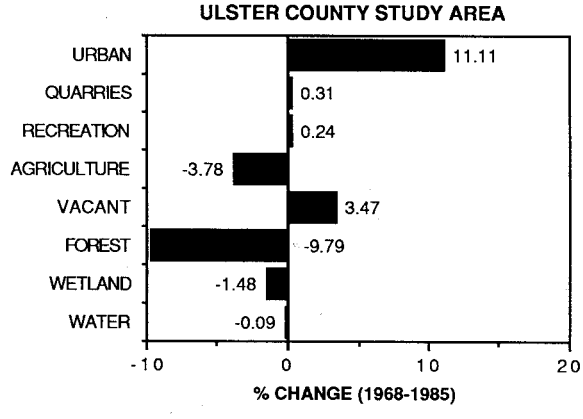

Fig. 2. Change between 1968 and 1985 in the percentage of the study area within each land use/land cover class.

3.1.1. Urban class

Urban class proportions for both 1968 and 1985 were negatively correlated with mean elevation (−.538, −.579) and with mean slope gradient (−.341, −.358), and were positively correlated with urban suitability (.430, .515). The variables accounting for 60% of the variance in the 1968 urban class proportions were highway proximity

Table 5. Land use/land cover transition matrix for fifteen minor civil divisions in Ulster County, New York.

	1985 land use (hectares)								
	Urban	Quarries	Recreation	Agriculture	Vacant	Forest	Wetland	Water	1968 totals
Urban	7,823.4	48.5	86.3	295.6	347.4	1,363.5	114.4	122.6	10,201.8
	(5.16)	(0.03)	(0.06)	(0.19)	(0.23)	(0.90)	(0.08)	(0.08)	(6.72)
Quarries	64.3	304.1	5.4	15.1	41.8	155.6	22.0	9.5	617.6
	(0.04)	(0.20)	*	*	(0.03)	(0.10)	(0.01)	*	(0.41)
Recreation	183.6	0.6	353.6	20.8	36.2	130.6	3.8	9.1	738.0
	(0.12)	*	(0.23)	(0.01)	(0.02)	(0.09)	*	*	(0.49)
Agriculture	2,938.4	79.6	75.3	8,524.8	4,682.6	2,517.0	233.2	150.1	19,200.9
	(1.94)	(0.05)	(0.05)	(5.62)	(3.09)	(1.66)	(0.15)	(0.10)	(12.65)
Vacant	1,676.8	43.9	83.8	1,198.8	2,466.8	2,026.3	111.2	30.0	7,637.6
	(1.11)	(0.03)	(0.06)	(0.79)	(1.63)	(1.34)	(0.07)	(0.02)	(5.03)
Forest	13,654.3	578.9	464.4	2,831.5	4,922.1	74,208.1	1,367.2	617.2	98,643.7
	(9.00)	(0.38)	(0.31)	(1.87)	(3.24)	(48.90)	(0.90)	(0.41)	(65.01)
Wetland	491.4	20.8	23.8	376.4	274.2	2,801.6	2,430.4	186.1	6,604.6
	(0.32)	(0.01)	(0.01)	(0.25)	(0.18)	(1.85)	(1.60)	(0.12)	(4.35)
Water	221.8	22.1	16.8	195.1	127.1	598.4	74.3	6,846.8	8,102.5
	(0.15)	(0.01)	*	(0.13)	(0.08)	(0.39)	(0.05)	(4.51)	(5.34)
1985 totals	27,053.7	1,098.4	1,109.3	13,458.1	12,898.2	83,801.0	4,356.4	7,971.4	151,746.8
	(17.83)	(0.72)	(0.73)	(8.87)	(8.50)	(55.22)	(2.87)	(5.25)	(100.00)

( ) = % of total study area; * = % < 0.01.

and 1968 population density (Table 7). After dropping four outliers (soil units 2, 30, 38, and 39), these two variables accounted for approximately 73% of the variance in the 1968 urban class proportions (LaGro 1991). Highway proximity, 1985 population density, and urban suitability accounted for 71% of the variance in the 1985 urban class proportions.

Between 1968 and 1985, urban land use increased from 6.7% to 17.8% of the study area. The change in urban class proportions was positively correlated with urban suitability (.531) and with highway proximity (.679), and was negatively correlated with mean elevation (−.535) and mean slope gradient (−.320). Highway proximity and urban suitability accounted for 65% of the variance in the change in urban class proportions. Urban development between 1968 and 1985 occurred, therefore, primarily on soil units that were relatively well-suited for urban uses, and were in relatively close proximity to heavy-duty, two-lane highways.

Although land predominantly in the forest class was converted to urban uses during this 17-year period, a substantial land area was also converted to urban uses from both the agriculture and vacant classes. The data suggest that more accessible and better-suited locations were preferentially selected for urban development. Between 1968 and 1985, for example, five soil units had an average increase of 9.9% (sd = 3.8%) in the area within the urban class, an average loss of 9.6% (sd = 2.7) in the forest class, and an average loss of 14.3% (sd = 5.6) in the agriculture class (Table 6). These five soil units have small mean slope gradients, low mean elevations, and relatively high farming suitability ratings.

3.1.2. Forest class

Forested areas in Ulster County comprise several distinct communities. Secondary forests less than fifty years old typically occur on land released from agricultural production, and comprise mostly deciduous pioneer species. Coniferous forest stands such as the even-aged red pine (*Pinus resinosa*) plantations, established in the 1930s under the US Department of Agriculture's soil conservation pro-

Table 6. Area and change in land use/land cover class percentages of forty-four general soil units* in the Ulster County study area.

Soil unit	Area (km²)	Urban	Agriculture	Forest	Vacant	Wetland
1	64.1	11.7	(19.5)	(10.4)	19.0	(1.0)
2	26.5	17.6	(4.9)	(12.5)	0.6	(2.3)
3	185.1	16.0	(2.0)	(13.7)	2.2	(2.3)
4	161.3	15.2	(1.5)	(15.4)	2.0	(1.6)
5	18.4	7.3	(1.3)	(8.8)	4.4	(0.7)
6	3.8	1.9	0.0	0.0	(1.9)	0.0
7	22.0	13.0	(1.9)	(15.5)	4.8	(0.3)
8	43.3	16.1	(8.0)	(6.0)	9.0	(1.5)
9	78.1	12.8	(2.2)	(12.1)	2.3	(1.2)
10	3.7	0.0	(0.2)	17.4	0.0	(17.3)
11	7.8	5.3	0.0	(5.3)	0.0	0.0
12	49.1	11.3	(5.0)	(6.4)	5.1	(5.3)
13	17.4	9.2	(0.5)	(11.3)	2.5	(0.7)
14	21.4	11.5	(0.9)	(9.7)	(0.1)	(1.8)
15			Not in study area			
16	49.3	1.5	(0.0)	(2.1)	0.3	0.3
17	6.7	3.9	(1.7)	12.2	(13.8)	0.0
18	13.9	0.8	0.2	(4.0)	(0.6)	1.4
19	10.5	(0.1)	0.0	0.7	(0.7)	0.0
20	16.4	9.1	(2.2)	(10.8)	0.6	(2.1)
21	145.9	10.5	0.2	(9.8)	0.1	(2.0)
22	51.6	3.4	0.1	0.3	(4.3)	(0.2)
23	8.0	14.8	(2.1)	(13.0)	(2.8)	0.0
24	52.6	3.2	0.0	(4.0)	1.4	(0.9)
25	2.7	0.0	0.0	6.0	(2.2)	(3.7)
26	15.0	21.7	0.0	(24.6)	2.9	0.0
27	18.3	6.9	(0.2)	(7.9)	2.4	(1.2)
28	11.3	20.9	(2.2)	(24.8)	4.7	(0.4)
29	16.6	10.9	(9.3)	(7.2)	10.5	(5.7)
30	28.4	5.9	(22.5)	(7.4)	23.6	(0.3)
31	6.0	11.4	(6.5)	(1.2)	2.8	(4.9)
32	31.1	9.4	(11.5)	(4.6)	5.8	(1.3)
33	59.1	13.7	(6.2)	(11.0)	5.0	(1.0)
34	19.7	17.9	(12.5)	(11.3)	9.5	(5.3)
35	3.0	17.2	(1.1)	(23.9)	7.7	0.0
36	34.7	15.4	(8.6)	(14.4)	12.6	(5.3)
37	1.5	0.1	(4.4)	(1.7)	8.8	(4.0)
38	8.0	18.7	0.1	(17.2)	(2.4)	(0.5)
39	38.6	18.3	(6.2)	(13.6)	0.6	(0.8)
40	1.9	6.0	(0.9)	(22.1)	9.9	0.0
41	18.3	6.3	(6.5)	(5.5)	2.7	5.2
42	11.2	5.9	(3.2)	(5.7)	0.4	0.9
43	18.5	5.4	(11.7)	(8.4)	14.1	3.6
44	23.3	5.8	(1.0)	(6.8)	0.3	0.9
45	8.9	7.7	(3.0)	2.3	3.3	(12.0)
Mean	32.6	9.6	(3.9)	(8.0)	3.5	(1.7)
S.Dev.	40.7	6.1	5.1	8.5	6.2	3.6

( ) = negative % change; * = excludes major water bodies.

grams, also exist within the study area. Other forest communities include intermediate-aged, mixed forests of the indigenous oak-beech-maple association and old-growth patches that are remnants of the region's primeval forests.

The 1968 and 1985 forest class proportions of the soil units were positively correlated with mean elevation (.738, .854), mean slope gradient (.833, .847), and distance from urban centers (.482, .508). The forest class proportions were also negatively correlated with urban suitability (−.334, −.385), farming suitability (−.512, −.565), and proximity to heavy-duty highways (−.412, −.535). Mean slope gradient, distance from urban centers, and urban suitability accounted for 82.0% of the variance in the 1968 forest class proportions (Table 7), and mean slope gradient, mean elevation, and urban suitability accounted for 87.0% of the variance in the 1985 forest class proportions. The correlation and regression results corroborate other evidence indicating that forested areas in both 1968 and 1985 were located predominantly on soil units relatively distant from the urban centers, with high mean elevations, high mean slope gradients, and soils poorly suited for either agricultural or urban uses.

Forested land in the study area decreased from 65.0% in 1968 to 55.2% in 1985, the largest decline of any land use/land cover class. The positive correlation between the change in forest class proportions and the 1968 vacant class proportions (.385) reflects the natural reforestation of vacant land that was released from agricultural production prior to 1968. Mean slope gradient was the only significant ($p < 0.05$) variable in the regression employing the change in forest class proportions as the dependent variable, although the explanatory power of this variable alone was relatively small.

On land where topographic barriers were slight and where soils were well-drained, forests were commonly replaced by farms and by urban development between 1968 and 1985. This deforestation was most pronounced at lower elevations, near cities and villages, and at locations near heavy-duty highways. Conversely, relatively steep or rocky areas within the county generally were allowed either to remain in, or revert back to, forest. Although the ecological, economic, and aesthetic impacts of the 10.2% loss in forest area have presumably varied with differences in the location and type of forest community displaced, assessing these impacts was beyond the scope of this study.

3.1.3. Agriculture class

In Ulster County, soils in the valley bottoms are well-suited for farming. High elevations and steep slopes, in contrast, are sites of rock outcrops and relatively shallow, stoney soils (US Department of Agriculture 1977). Accelerated soil losses and difficulty in operating farm equipment are associated with farming on steep slopes. Differences in the suitability of the soil units for farming are reflected by the inverse relationships between farming suitability and both mean elevation (−.562) and mean slope gradient (−.564). The agriculture class proportions for 1968 and 1985 were negatively correlated with mean elevation (−.601, −.524) and mean slope gradient (−.603, −.533), and were positively correlated with farming suitability (.653, .594). Mean elevation, 1968 population density, and mean slope gradient accounted for 52% of the variance in the 1968 agriculture class proportions (Table 7). By dropping one outlier (soil unit 41) from the regression, this was increased to 64%. Farming suitability and mean slope gradient accounted for only 37% of the variance in the 1985 agriculture class proportions, although by dropping four outliers (soil units 21, 39, 41, and 42) from the regression, 61% of the variance in the 1985 agriculture class proportions was accounted for by these two variables.

Land in the agriculture class declined from 12.7% of the study area in 1968 to 8.9% in 1985. The negative correlation between the change in agriculture class proportions and the change in vacant class proportions (−.796) reflects a substantial release of land from agricultural production. The change between 1968 and 1985 in agriculture class proportions was negatively correlated with farming suitability (−.564), and positively correlated with mean elevation (.572) and mean slope gradient (.557). Approximately 53% of the variance in the change in agriculture class proportions was accounted for by 1985 population density, mean elevation, and mean slope gradient. The estimated

Table 7. Least squares regression estimates for the logit of the five major land use/land cover class proportions on the site, location, and demographic variables (weighted analyses).

Y	X_i	Parameter estimate	t-statistic	Adjusted R2
URB68	INTERCEPT	−0.1824	−3.683	0.6038
	ROADPROX	0.2245	4.674	
	68DENS	0.0505	3.645	
URB85	INTERCEPT	−0.2513	−2.550	0.7059
	ROADPROX	0.4007	4.840	
	85DENS	0.0794	3.114	
	URBSUIT	0.1271	2.273	
URBCHG	INTERCEPT	0.0579	5.131	0.6521
	ROADPROX	0.2343	5.800	
	URBSUIT	0.0889	2.936	
FOR68	INTERCEPT	−1.8894	−3.623	0.8198
	SLOPE	1.1633	9.905	
	URBDIST	0.6177	2.624	
	URBSUIT	−0.5502	−2.072	
FOR85	INTERCEPT	−2.7692	−5.199	0.8701
	SLOPE	0.7304	7.409	
	ELEV	0.5339	4.343	
	URBSUIT	−0.4496	−2.435	
FORCHG	INTERCEPT	0.0949	0.714	0.2312
	SLOPE	−0.2753	−3.733	
AGR68	INTERCEPT	1.7902	5.203	0.5208
	ELEV	−0.2058	−3.612	
	68DENS	−0.1146	−3.274	
	SLOPE	−0.0923	−2.239	
AGR85	INTERCEPT	0.1492	2.444	0.3659
	FARMSUIT	0.1452	3.071	
	SLOPE	−0.0641	−2.299	
AGRCHG	INTERCEPT	−0.8422	−5.452	0.5315
	85DENS	0.0719	4.199	
	ELEV	0.0842	3.673	
	SLOPE	0.0403	2.482	
VAC68	INTERCEPT	0.6408	7.266	0.5150
	ELEV	−0.0821	−6.882	
	68DENS	−0.0449	−4.682	
VAC85	INTERCEPT	1.6430	7.218	0.5105
	ELEV	−0.2187	−6.778	
	68DENS	−0.1029	−4.335	
	ROADPROX	−0.1683	−2.081	
VACCHG	INTERCEPT	0.9664	5.927	0.4093
	ROADPROX	−0.1299	−2.242	
	ELEV	−0.1299	−5.624	
	68DENS	−0.0601	−3.536	
WET68	INTERCEPT	−0.9916	−2.839	0.5474
	SLOPE	−0.2222	−6.391	
	ELEV	0.2287	4.238	
	68DENS	0.0863	2.760	
	FARMSUIT	−0.1184	−2.278	
WET85	INTERCEPT	−0.0997	−0.488	0.3536
	SLOPE	−0.1641	−4.646	
	FARMSUIT	−0.1353	−2.730	
	ELEV	0.0956	2.135	
WETCHG	INTERCEPT	0.4895	5.066	0.4954
	SLOPE	0.0563	5.541	
	ELEV	−0.0866	−6.040	
	85DENS	−0.0410	−3.827	

parameter coefficient for each variable was positive, reflecting the relatively extensive losses of agricultural land that occurred on soil units at low elevations and with gentle slopes.

Compared to much of the steep terrain in Ulster County, the most suitable farmland within the study area presents few physical obstacles to the construction of roads, utility systems, and buildings. Although agricultural land in both 1968 and 1985 was generally well-suited for farming, the release of land from agriculture disproportionately occurred on the general soil units with low mean elevations, small mean slope gradients, and high farming suitability ratings. The nine soil units with the highest farming suitability ratings in the study area averaged 7.5% (sd 6.1) losses in the agriculture class between 1968 and 1985. The average loss in the agriculture class for the remaining thirty-three soil units in the study area was only 3.0% (sd = 4.4). Because Ulster County has long been New York State's largest producer of fresh market apples and sweet corn, with a total market value of farm products exceeding $40 million in 1982 (Ulster County Planning Board 1984), continued losses of high quality farmland could have significant economic consequences for the county.

3.1.4. Vacant, barren, and transitional class

Vacant class proportions for 1968 and 1985 were negatively correlated with distance from urban centers (−.419, −.266), mean elevation (−.407, −.485), and mean slope gradient (−.356, −.474). They were also positively correlated with farming suitability (.379, .473) and 1968 agriculture class proportions (.381, .482). Mean elevation and 1968 population density accounted for 52% of the variance in the 1968 vacant class proportions (Table 7). Approximately 51% of the variance in the 1985 vacant class proportions was accounted for by mean elevation, 1968 population density, and highway proximity. The negative parameter coefficients in both regression equations reflect the relatively large areas of vacant land that were located on soil units within the less accessible, rural parts of the study area.

The vacant class increased from 5.0% of the study area in 1968 to 8.5% in 1985. About one-third of the land in the 1968 vacant class remained within that class in 1985, while smaller proportions of the vacant class were converted by 1985 to the agriculture and forest classes (Table 5). The change in vacant class proportions was negatively correlated with the change in agriculture class proportions (−.796), mean elevation (−.417), and mean slope gradient (−.433). Approximately 41% of the variance in the change in vacant class proportions was accounted for by highway proximity, mean elevation, and 1968 population density. This suggests that the larger increases in vacant land occurred primarily at lower elevations and in less populated rural areas.

The correlation and regression results reflect both a reforestation of vacant land at higher elevations and a release of land from agricultural production at lower elevations. Land released from agricultural production generally was converted to either the forest or urban classes. Inspection of the aerial photographs revealed that, between 1968 and 1985, the idling of agricultural land was accompanied in most townships by the conversion of former agricultural land to urban uses, and by the reforestation of vacant land idled prior to 1968. This is consistent with the transition matrix data showing strong successional pathways from agricultural to vacant uses, and from vacant to urban uses.

3.1.5. Wetland class

Approximately 55% of the variance in the 1968 wetland class proportions was accounted for by mean slope gradient, mean elevation, 1968 population density, and farming suitability (Table 7). Only 35% of the variance in the 1985 wetland class proportions was accounted for by mean slope gradient, farming suitability, and mean elevation. Although wetlands occurred in both 1968 and 1985 throughout the study area, the positive coefficient estimates for the mean elevation variable reflect the disproportionate location of forested wetlands at relatively high elevations. Conversely, the paucity of wetlands at low elevations is a result of the widespread wetlands destruction that occurred prior to 1968 through agricultural expansion, residential development, highway construction, and other human activities.

Between 1968 and 1985, wetlands declined from 4.4% to 2.9% of the study area. Approximately 50% of the variance in the change in wetland class proportions was accounted for by mean slope gradient, mean elevation, and 1985 population density. The change in forest class proportions was negatively correlated with the change in wetland class proportions (−.334). This corroborates the data in the transition matrix (Table 5), showing that a large majority of the land in the 1968 wetland class changed to the forest class by 1985. These findings suggest that the loss of wetlands between 1968 and 1985 could be largely attributable to the drying of ephemeral forested wetlands, which resulted in their reclassification as forested areas in 1985.

4. Conclusions

Several broad patterns have emerged from this analysis of land use change in the Ulster County study area. Land use changes between 1968 and 1985 involved major transitions of land from the forest, agriculture, and vacant classes to the urban class. Other important changes included transitions to the vacant and forest classes from the agriculture class, and transitions to the forest and agriculture classes from the vacant class. These findings are consistent with the results of other research on landscape change within or near the urban-rural fringe (Zeimetz *et al.* 1976; Heimlich and Anderson 1987; Befort *et al.* 1988; Vesterby and Heimlich 1991).

Many factors are at least indirectly responsible for the land use changes that have occurred in the study area. Gains in agricultural productivity, attained significantly through technological advances and fossil fuel inputs, have stimulated the release of lands from agricultural production. Economic restructuring, infrastructure expansion, and advances in telecommunication technology have facilitated the redistribution of resources and population within the state. Population deconcentration has resulted in the conversion of farms and forests in the study area to residential, commercial, public, and transportation uses. A substantial demand for leisure activities has also generated a nearly 50% increase in the land area devoted to outdoor recreation. Although a large proportion of former farmland was converted to urban uses, a smaller but sizeable proportion was allowed to resume secondary succession. This has resulted in the reforestation of less accessible rural lands that are largely unsuited for agriculture. The cumulative effects of these changes has been the incremental conversion of an agricultural, and largely forested, landscape to a landscape substantially altered by spatially dispersed urban development.

Quantifying the relationships between land use spatio-temporal patterns and ancillary biological, physiographic, and socioeconomic factors can help clarify the linkages between population dynamics, land use change, and environmental degradation. Interdisciplinary research is particularly needed to investigate these relationships in urbanizing landscapes, where humans increasingly play a dominant role in precipitating landscape change. The general soil unit would be a viable unit of analysis for this type of research, because general soil units are smaller than counties, minor civil divisions, and soil associations, and are more homogeneous than these units in characteristics such as slope gradient, elevation, and soil fertility. The soil series is a unit of even finer spatial resolution, however, and perhaps would be more appropriate for detailed ecological analyses.

Although field studies were not conducted in this research to quantify the impacts of land use change on water quality, species abundance and diversity, or a variety of other indicators of environmental quality, these analyses could benefit from the integration of detailed spatial data in a geographic information system. Because urban development poses a substantial threat to environmental quality, a major goal of future landscape ecological research should be to assess the environmental impacts of land use change within the urban-rural fringe.

Acknowledgments

This research was funded, in part, by a National Audubon Graduate Student Research Award, by a Hewlett Foundation Research Award to the Cornell Center for the Environment, and by the Cornell

Laboratory for Environmental Applications of Remote Sensing. The authors gratefully acknowledge the constructive comments made on an early draft of this paper by an anonymous reviewer, and by David Brown, David Pimentel, and Sidney Saltzman.

References

Anderson, J.R., Hardy, E.E., Roach, J.T. and Witmer, R.E. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964, U.S. Government Printing Office: Washington, D.C. 48pp.

Befort, W.A., Luloff, A.E. and Morrone, M. 1988. Rural land use and demographic change in a rapidly urbanizing environment. Landscape and Urban Planning, 16: 345–356.

Brown, D.L. and Wardwell, J.M., eds. 1980. New Directions in Urban-Rural Migration. New York, Academic Press. 412pp.

Chatterjee, S. and Price, B. 1977. Regression Analysis By Example. New York: John Wiley and Sons. 228pp.

Diamond, D.B. Jr. and Tolley, G.S., eds. 1982. The Economics of Urban Amenities. Academic Press, Inc., New York. 226pp.

ERDAS, Inc. 1988. ERDAS Geographic Information System/ Image Processing Software, Release 7.3. Atlanta, Georgia.

Freund, R.J. and Littel, R.C. 1986. SAS System for Regression. SAS Institute, Inc., Cary, North Carolina. 164pp.

Fuguitt, G.V., Voss, P.R. and Doherty, J.C. 1979. Growth and Change in Rural America. Urban Land Institute, Washington, DC. 101pp.

Fuguitt, G.V., Brown, D.L. and Beale, C.L. 1989. Rural and Small Town America. Russell Sage Foundation, New York. 471pp.

Fuguitt, G.V. and Brown, D.L. 1991. Residential preferences and population redistribution: 1972–1988. Demography, 27(4): 589–600.

Heimlich, R.E. and Anderson, W.D. 1987. Dynamics of land use change in urbanizing areas: experience in the Economic Research Service, pp.135–154. *In* Sustaining Agriculture Near Cities. W. Lockeretz, ed. Ankeny, Iowa: Soil and Water Conservation Society.

Ingram, A. 1989. Personal Communication. Aerial Photograph Analyst, Cornell Laboratory for Environmental Applications of Remote Sensing. Cornell University, Ithaca, New York.

Iverson, L.R. 1989. Land use changes in Illinois, USA: the influence of landscape attributes on current and historic land use. Landscape Ecology, 2(1): 45–61.

Jensen, J.R., ed. 1983. Urban/suburban land use analysis. *In* Manual of Remote Sensing, 2nd ed. pp.1571–1666. Edited by R.N. Colwell. American Society of Photogrammetry, Falls Church, Virginia.

Johnston, R.J. 1984. Quantitative ecological analysis in human geography: an evaluation of four problem areas. *In* Recent Developments in Spatial Data Analysis: Methodology, Measurement, Models. pp.131–141. Edited by G. Bahrenberg, M.M. Fischer and P. Nijkamp. Gower, Brookfield, Vermont.

Knapp, T.A. and Graves, P.E. 1989. On the role of amenities in models of migration and regional development. Journal of Regional Science, 29(1): 71–87.

LaGro, James A. Jr. 1991. Population Deconcentration and Land Use Change Within a Non-Metropolitan County in New York State. Unpublished Ph.D. dissertation, Cornell University, Ithaca, New York. 233pp.

Lewis-Beck, M.S. 1980. Applied Regression: An Introduction. Sage University Paper Series on Quantitative Applications in the Social Sciences, series no. 07-022. Sage Publications, Beverly Hills and London. 79pp.

Mallows, C.P. 1973. Some comments on C(p). Technometrics, 15: 661–675.

New York State Office of Planning Coordination. 1971. LUNR (Land Use and Natural Resource Inventory) Classification Manual. Albany, New York: State of New York Office of Planning Coordination. 21pp.

Platt, R.H. and Macinko, G., eds. 1983. Beyond the Urban Fringe: Land Use Issues of Nonmetropolitan America. University of Minnesota Press, Minneapolis. 416pp.

Snedecor, G.W. and Cochran, W.G. 1980. Statistical Methods, 7th ed. The Iowa State University Press, Ames, Iowa. 507pp.

Ulster County Planning Board. 1984. Ulster County Data Book. Kingston, New York: Ulster County Planning Board. 151pp.

US Bureau of the Census. 1982. 1980 Census of Population. Vol. I. Characteristics of the Population. Chapter A, Number of Inhabitants. Washington, DC: US Government Printing Office.

US Bureau of the Census. 1988. Local Population Estimates, Series P-26, No. 86, Northeast 1986 Population and 1985 Per Capita Income Estimates for Counties and Incorporated Places. Washington, D.C.: U.S. Government Printing Office.

US Department of Agriculture. 1977. General Soil Map and Interpretations; Ulster County, New York. Hyattsville, Maryland: USDA Soil Conservation Service. 108pp.

US Geological Survey. 1987. Digital Elevation Models: Data Users Guide #5. Reston, Virginia: US Geological Survey. 38pp.

Vesterby, M. and Heimlich, R.E. 1991. Land use and demographic change: results from fast-growth counties. Land Economics, 67(3): 279–291.

Wardwell, J.M. 1980. Toward a theory of urban-rural migration in the developed world. *In* New Directions in Urban-Rural Migration. pp.71–114. Edited by D.L. Brown and Wardwell, J.M. Academic Press, New York.

Zeimetz, K.A., Dillon, E., Hardy, E.E. and Otte, R.C. 1976. Dynamics of Land Use in Fast-Growth Areas. Agricultural Economic Report No. 325, Economic Research Service, USDA. Washington, DC: US Government Printing Office. 48pp.

Zuiches, J.J. 1981. Residential Preferences in the United States. *In* Nonmetropolitan America in Transition. pp.72–115. Edited by A.H. Hawley and S.M. Mazie. The University of North Carolina Press, Chapel Hill.