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## **Socioeconomic Influences on Land Use Choice at Watershed Level – A Multinomial Logit Analysis of Land Use Distribution in West Georgia**

Gandhi Bhattarai  
Graduate Research Assistant  
Agricultural Economics and Rural Sociology  
Auburn University  
Auburn, AL 36849  
Tel: 334-844-5685  
e-mail: [bhattgr@auburn.edu](mailto:bhattgr@auburn.edu)

Upton Hatch  
Professor  
Auburn University Environmental Institute  
Auburn, AL 36849  
Tel: 334-844-5609  
e-mail: [hatchlu@auburn.edu](mailto:hatchlu@auburn.edu)

Daowei Zhang  
Professor  
School of Forestry and Wildlife Sciences  
Auburn University  
Auburn, AL 36849  
e-mail: [zhangd@auburn.edu](mailto:zhangd@auburn.edu)

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# **Socioeconomic Influences on Land Use Distribution at Watershed Level: A Multinomial Logit Analysis of Land Use Distribution in West Georgia**

Gandhi Bhattarai, Upton Hatch and Daowei Zhang

## **Abstract**

*Allocation of fixed proportion of land to developed, forest, agricultural and other land uses in a watershed was modeled as an optimization problem faced by a single user. A multinomial logit model was used to estimate the effects of urbanization, demographic structure, personal income and spatial distribution of watersheds.*

Keywords: multinomial logit, land use distribution

## **Introduction**

The southeast region of the United States has experienced tremendous urban expansion and market influence in the past forty years. Increasing population and economic activities demand more land for development purposes; such as more home sites, roads, airports, schools, parks and industrial and commercial developments. Population growth and increase in per capita disposable income have been important components of the economic demand for urban land uses (Reynolds, 2001). As a result, more land has been cleared of forest for cultivation and more agricultural lands have been used to satisfy increasing demand for urban development. Urban areas have become more intensified and they have expanded into rural areas to accommodate the

demand for urban land uses. This has created strong competition between urban expansion and agriculture, forestry and other rural land use (Reynolds, 2000).

The Georgia piedmont has experienced very rapid annual development and ranks among the highest regions in terms of percent increase in developed land area during the 1990s (USDA-NRCS). Georgia ranked 6<sup>th</sup> among the fastest growing states, with a population growth of 26.4% between 1990 and 2000 census years (CensusScope). Columbus, Georgia, is a rapidly growing urban area in the southeast. The population in Columbus Metropolitan area increased from 260,860 in 1990 to 274,624 in 2000, a 5.3% increase in 10 years. With limited scope of expansion due to Chattahoochee river in the west and a defense base on the south, the area is expanding to the north and east at a rapid rate. Muscogee, the county where major portion of Columbus Metropolitan Area is contained, experienced only 3.9% increase in population. Harris, a neighboring county, experienced a record 33.9% population growth in the same period. Land in development use increased by 170% while forest and agricultural uses declined by 6% and 13%, respectively. The whole area has gone through a rapid transformation from rural to developed land over a short period of time and provided an excellent site for this study. However, areas far from the metropolitan areas are still predominantly rural with low population growth.

The level of economic activities, demographic changes and public policies related to land management are associated with the distribution of agricultural, forest, urban and other lands in an area. The conversion of land use from forest to agriculture or to residential development tends to be permanent and irreversible. Increased land use in agriculture results in larger quantities of chemicals and pesticides being used, thus causing higher non-point source pollution of ground and surface water. Clear cutting forests results in the loss of habitat for wildlife and increases

runoff as the protective vegetative cover of the soil is lost. Urban development increases the amount of impervious surface and causes higher run-off and water pollution through urban wastes. Combination of all these factors contributes to the water stress, pollution and loss of aquatic and terrestrial biodiversity. Understanding the causes and effects of land use change helps in making public policy towards land development such as zoning. This study develops an econometric model to explain the changes in land use distribution as a function of different levels of demographic, economic and market conditions at the watershed level using time-series cross-sectional data.

### **Framework for Econometric Analysis**

Most land use studies have lately focused on urban sprawl and its effect on agricultural land values, farmland retention and some relationship between the rural-urban interfaces (e.g., Baumol and Oates, 1998; Bearlieu et al., 1998; Onal et al, 1997; Phinn and Stanford, 2001; Reynolds, 2001; Wear and Bolstad, 1998). Those studies have focused on the effect of urbanization in the agricultural land values, agricultural and forest interaction, urban-rural interface and land use competition, using land use change as a function of particular regulation, economic activity and population growth at micro level. However, the nature of land use conversion over a wider geographic coverage with respect to the population changes, economic growth and market pressure is not fully explained.

Population growth, urban development, and personal income from non-farm sources are expected to encourage conversion of low return forest and agricultural land to high return developmental use. Increased demand for developmental land causes sharp increase in the price

of land in city centers, which gradually expand to the surrounding areas in search of relatively cheaper land, thus reducing the effect of urban expansion with gradual increase of distance from major populated places and city centers. While the commute time to regular work is an indicator of high traffic urban areas, the proportion of employed population working within the place of living also indicates a market concentration in the area. Similarly, population structure such as average age and education level of population also affects how people decide to allocate their land in alternative uses.

In this study, the allocation of fixed proportion of lands to different developed, agricultural, forest and other uses in a watershed was viewed as an optimization problem faced by a single user. The following mathematical model has been used to explain the effect on land use distribution in a watershed:

$$\text{Land use} = f(\text{population density, average age, personal income, level of education, availability of local jobs, travel time to work, accessibility, spatial location}).$$

The variables such as ratio people working within a place, travel time to work, and transportation and commercial infrastructure were taken as the indicators of urban development and concentration. Similarly, population density, average age of population, and education level -as expressed by the ratio of population with bachelors and higher degrees, were taken as the indicator of demographic structure. Personal income was the indicator of economic development in the area. Relative spatial location was expressed in terms of longitude and latitude of the centroid of watershed. A significant coefficient of longitude and latitudes would suggest spatial dependence in land use distribution by watersheds.

A modified multinomial logit model from Parks (1980) was used for the analysis. Land use in each category was expressed as a share of total area of lands in the watershed in which the sum of the probabilities of all categories equals one.

$$P_{ikt} = \frac{\exp(\beta'_k X_{it})}{\sum_{k=1}^K \exp(\beta'_k X_{it})} \quad (1)$$

where  $p$  is the proportion of land in  $i$ -th watershed, in  $k$ -th use and at time  $t$ .  $X$  represents a vector of demographic, economic and spatial characteristics for the observed individual watershed.  $\beta_{it}$  is a vector of estimated parameters.

Normalization of the shares by one of the categories ( $\beta_k=0$ ) yields the multinomial logit model as:

$$P_{ikt} = \frac{\exp(\beta'_k X_{it})}{1 + \sum_{k=1}^{K-1} \exp(\beta'_k X_{it})} \quad \text{for } k=1, 2, \dots, K-1 \quad (2)$$

The proportion of omitted ( $K^{th}$ ) category was derived from the formula:

$$P_{ikt} = \frac{1}{1 + \sum_{k=1}^{K-1} \exp(\beta'_k X_{it})} \quad (3)$$

A logarithmic transformation of (1) gave the following three equations:

$$\ln(y_{ikt} / y_{it}) = \beta_k X_{it} \quad \text{for } k = 1, 2, 3 \quad (4)$$

$Y_{ikt}$  represents not directly observable optimal shares of land use. Unobserved optimal share of land use were replaced with observed ratio of land use shares for the model estimation.

Since the coefficients of such models are not directly interpreted in contrast to OLS results, marginal effects were estimated to express the probability of change in land use with respect to each independent variables, measured from the mean of the variable.

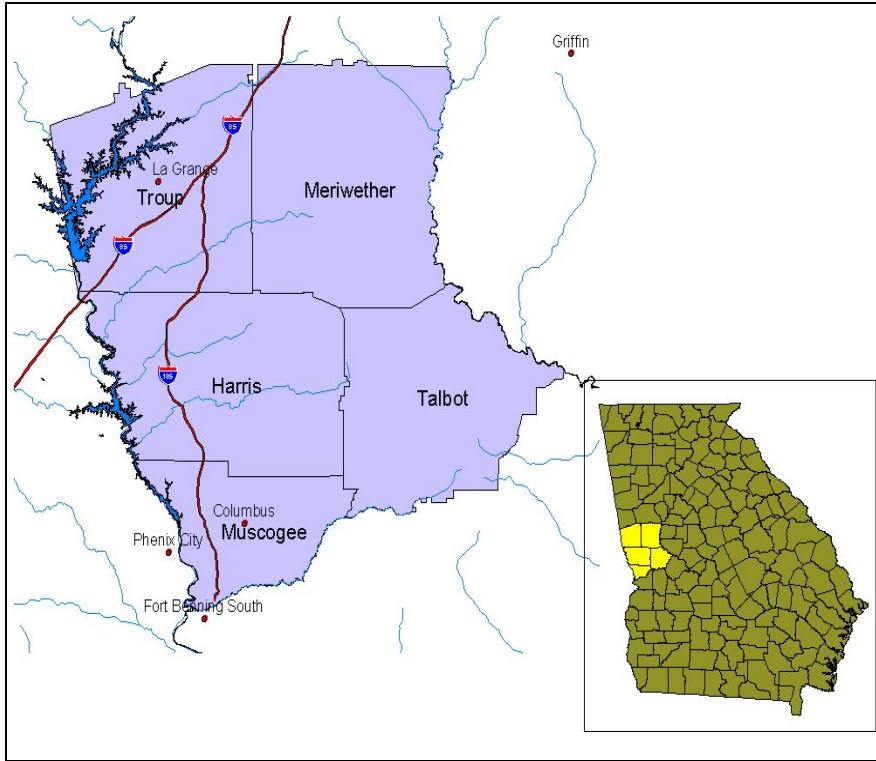
$$\frac{\partial p_{ikt}}{\partial x_{ikt}} = \left( \beta_{kx} - \sum_{k=1}^{K-1} p_{ikt} \cdot \beta_{kx} \right) p_{ikt} \quad \text{for } k=1, 2, \dots, K-1 \quad (5)$$

where  $\beta_{kx}$  is the coefficient of  $x$  for land use  $k$ . The marginal effect on the redundant category is obvious as the sum of the marginal effects of all categories equals to zero.

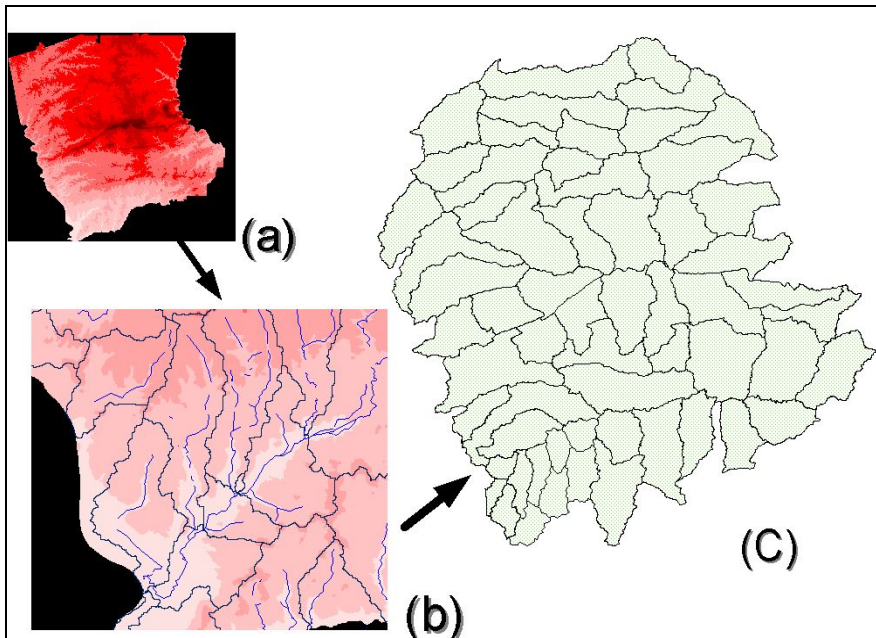
## Data and GIS Methods

Five western Georgia counties, Harris, Meriwether, Muskogee, Talbot and Troup were selected to represent different transitions of land use change in the study area. A location map of study area is given in Figure 1. The extent of analysis was watershed level and watersheds were delineated using 'Hydrological Modeling Extension' tool available in ArcView GIS. National Elevation Model (NEM) data with 30x30 m resolution (1:24,000 scale) was used for delineating watersheds. A total of 60 watersheds were selected within the five counties boundaries, which ranged in size from 2,693 acres to 30,643 acres with a mean of 16,556 acres. A diagrammatic representation of stepwise process and map of hydrological units is given in Figure 2.





**Figure 1.** Map of study area with reference to Georgia map

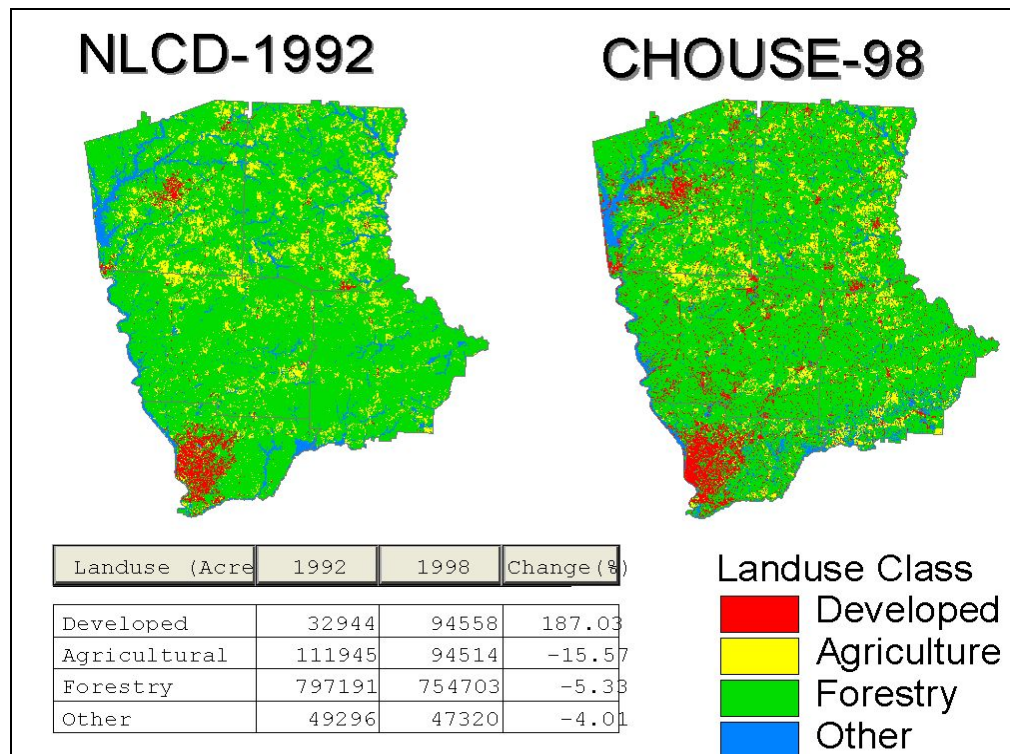


**Figure 2.** Hydrological Modeling process: (a) preprocessing DEM data; (b) watershed delineation; (c) watershed processing and attributes.

Methodologically, most land use change studies are based on comparative study of two satellite images taken at different time periods (Phin and Stanford). In the recent years, formation of Multi-Resolution Landuse Consortium (MLRC) has made it possible to use a uniform land use category developed from multiple satellite image processing taken over a wider period of time. The resulting digital maps show a more stable land use distribution and indicate a permanent change when they occur. A 21-class digital land cover map of study area was extracted from USGS National Land Cover Dataset (NLCD) for 1992, hereafter called NLCD-92. This land use map was based on the satellite images taken during the period from 1988 to 1991. Similar map was obtained from Georgia GIS Data Clearing House for year 1998, hereafter called CHOUSE-98, which was based on the satellite images taken during 1996-1998. Those digital maps were converted to standard grids to facilitate reclassification and spatial analysis. Land use grids for the wider five county areas were extracted using 'Extract Grids by Polygon' feature in the 'Grid Analysis Extension'. The land cover reclassification scheme is given in Appendix 1. Extracted grids were reclassified using 'reclassify' tool within the 'Spatial Analysis' extension in ArcView GIS. The reclassified grids were tabulated for each of the watershed polygons using 'Tabulate' feature. A comparison of land use change for the whole study area between NLCD-92 and CHOUSE-98 is given in Figure 3.

Census Block Group (CBG) level housing and population data (Census Bureau: STF3A Microdata) was extracted from the Interuniversity Consortium for PSR database. Demographic and economic data for a total of 242 CBS in 1992 and 226 CBG in 2000 were extracted. ICPSR was available for free, along with the SAS or SPSS program to read data, to the participating universities. Processed data contained information related to population structure such as total counts and percentages in rural versus urban area, age structure, personal and household income,

education, family structure, characteristics and counts of housing units, median house value among others. All monetary values were deflated for base year 1982-84 = 100.



**Figure 3. Broad (reclassified) land use distribution in the study area**

Census Block Group TIGER line data were taken from ESRI for both years. The processed socioeconomic data that were in tabular form in a database were spatially joined with the TIGER line table. The set of CBG polygons and watershed polygons were intersected to derive segments of polygons from both of the themes. The area of each segment and its ratio to the source CBG was calculated. Assuming a uniform distribution of information within each CBG, this ratio was applied to calculate the weighted counts and averages for each of the watersheds that contained multiple of such segments. Once this had been done, data were read and further processed with SAS program.

## Results and Discussions

A descriptive statistics of the study variables is given in Table 1. It is interesting to note that the population density and the average age of population both increased by 5% between two census periods.

**Table 1. Descriptive statistics of variables used in the study**

Variables	Census'90/NLCD-92		Census'00/CHOUSE-98		Change
	Mean	Std.	Mean	Std.	%
Population density	0.121	0.118	0.127	0.113	5%
Average age	35.027	2.544	36.868	2.437	5%
Local job ratio	0.275	0.317	0.251	0.317	-9%
Travel time to work	23.112	4.584	27.196	6.527	18%
Transportation network	0.020	0.042	0.084	0.080	323%
Personal income	8.790	2.824	10.853	3.279	23%
Education level	0.148	0.078	0.193	0.095	31%
Longitude (X-Coord)	-84.823	0.167	-84.823	0.167	0%
Latitude (Y-Coord.)	32.786	0.203	32.786	0.203	0%
Landuse distribution (ratio)					
Developed	0.077	0.182	0.145	0.191	87%
Agricultural	0.104	0.063	0.084	0.060	-19%
Forestry	0.773	0.172	0.723	0.176	-6%
Other	0.045	0.034	0.047	0.040	5%

In general, number of people working at the place of living decreased by 9% while travel time to work increased by 18%. If the assumptions are supported by the analysis later, this pattern would provide evidence of urban traffic congestion and rural urban job interface. Land in commercial, industrial, and transportation network increased by 323 percent. Per capita income increased by 23% and proportion of population with bachelors and higher degree increased by 31%. Assumptions were made in this line when simulating predicted land use change later.

The model was determined as systems of equations in which equations for developed land, agricultural land and forest land shares were jointly determined using iterated seemingly unrelated regression (ITSUR). Both the Bruesch-Pagan and White's test showed presence of heteroskedasticity with the variables population density, local job ratio in developed land model. An attempt to correct heteroskedasticity by weighting the local job ratio and population density further worsened the error structure while weighting for average age resulted in non-significant test statistics at 5% level of significance.

The results of the heteroskedasticity corrected regression models are given in Table 2. The parameter coefficients of such models are difficult to interpret directly. Instead the marginal effects are the only means to effectively interpret the effect of explanatory variables on the distribution of proportion of dependent variables. Marginal effects are the probability of change in land use with respect to each independent variable, measured from the mean of that variable. A positive or negative sign of marginal effects, the only reliable indicator in such models, indicates an increase or decrease in the proportion of land in that use. Since the proportion of land in all land use class should equal to one, the marginal effects of explanatory variables on the redundant category is obvious. Table 2 includes the results for estimation, marginal effects and elasticity of each of the variables in each of the jointly determined models.

**Table 2. Results of multinomial logit model**

Variables	Developed			Agricultural			Forestry		
	Coeff.	Marginal Effects	Elast.	Coeff.	Marginal Effects	Elast.	Coeff	Marginal Effects	Elast.
Intercept	-239.76 ** (114.5)			-7.421 (63.669)			10.425 (50.483)		
Population density	1.295 (2.235)	-0.015	-0.050	2.432 * (1.242)	0.062	0.088	1.747 * (0.985)	0.023	0.003
Average age	0.161 ** (0.076)	0.004	4.190	0.055 (0.042)	0.001	0.370	0.041 (0.033)	-0.003	-0.132
Work in place	2.98 ** (1.192)	0.139	1.060	-0.825 (0.662)	0.019	0.058	-1.285 ** (0.525)	-0.201	-0.063
Travel time to work	0.114 ** (0.045)	0.005	3.810	-0.057 ** (0.025)	-0.002	-0.486	-0.044 ** (0.02)	-0.005	-0.152
Road Network	5.357 (3.516)	0.213	0.320	-0.506 (1.955)	0.027	0.016	-1.145 (1.55)	-0.273	-0.017
Per capita income	-0.006 (0.124)	0.003	0.860	-0.198 *** (0.069)	-0.009	-1.027	-0.09 (0.055)	0.002	0.027
Education level	2.407 (4.54)	-0.037	-0.180	5.727 ** (2.524)	0.196	0.383	3.458 * (2.00)	-0.017	-0.003
X-Coordinate	-2.354 * (1.382)	-0.071	175.71	0.085 (0.768)	0.032	-31.170	-0.249 (0.609)	0.028	-2.810
Y-Coordinate	0.906 (1.11)	0.054		0.481 (0.617)	0.099		-0.867 (0.489)	-0.179	
Adjusted R <sup>2</sup>	0.30			0.12			0.08		
Obs.	120			120			120		

Though the marginal effects of population density in developed land was negative but non-significant, they were positive for both agricultural and forest land share and negative for other land share. It is assumed that conversion of cotton land to forest land and streamside management practices in recent years contributed increase in forest share while other lands including wetland, water bodies and barren lands were impacted by increasing population.

Higher education level, as measured by the ratio of population with bachelors and above degrees, increased the proportion of agricultural land share and reduced all other land uses. It is assumed that more people with technical skills come to intensify agricultural production, while low educated persons seek for urban jobs and manage their land less intensively such as by growing forests.

Average travel time to work has significant effects in all land use shares. Increased developed land share was associated with increasing average travel time to work, while that of agricultural and forest land shares were decreased with it. Availability of jobs in the place of living, as measured by the proportion of employed people working in the place of living, was significant for developed land share (positive) and forest land share (negative). Market concentration and more jobs in the area was associated with more land conversion from forest to developmental uses.

Though not significant for any model, the ratio of commercial/industrial/transportation land to the total land positively affected the share of developed land and agricultural land shares while decreased the forest and other land shares.

Per capita income was not significant in determining the share of developed and forest land while it significantly decreased the share of agricultural land.

Longitude value was significant and influenced negatively the share of developed land while influencing positively to the agricultural and forest land shares. Latitude values were not significant for any models and had positive marginal effect with developed, agricultural and other land, and negative effect in forest and other land. Everything else equal, the proportion of developed land would decrease when moving from west to the east. Similarly, the proportion of forest land use would decrease towards the north and increase towards the east direction. Agricultural land share would increase when moving towards north and to the east. These spatial marginal effects confirm with the spatial pattern of urban development in the study area.

## **Conclusions**

This study developed an econometric model to explain the land use distribution at watershed level in five West Georgia counties. A multinomial logit model (Parks 1980) was used to explain the effect of population density, mean age, market concentration (job availability at place level), travel time to work, road accessibility, personal income, education level and longitude and latitude of watersheds. Developed land use share was positively related to the higher market concentration and road accessibility, but with higher average time to work, suggesting a rural-urban job interface. Personal income had only significant and negative influence in agricultural land share, which in contrast, was increased with higher proportion of people with bachelors and graduate degrees. Longitude had negative influence in developed land share and positive influence in agricultural, forest and other land use. Latitude had positive influence in developed, agricultural and other land share while negatively influencing forest land share. These results suggested a spatial pattern of land use distribution in the study area as evidenced by the land use map in Figure 3.



## References

- Anselin, L. 2001. Spatial Effects in Econometric Practice in Environmental and Resource Economics. *American Journal of Agricultural Economics*, 83(3): pp. 705-710.
- Baumol, W. J. and Oates, W. E. 1998. The Theory of Environmental Policy, 2<sup>nd</sup> Ed. Cambridge University Press.
- Bearlieu, J., Bennett, D., Kraft, S. and Sengupta, R. 1998. Ecological-Economic Modelling on a Watershed Basis: a case study of the cache river of Southern Illinois. Paper presented at the AAEA Annual meeting, Salt Lake City, Utah, 1998.
- CensusScope, 2003. <http://www.censusscope.org>. Accessed on 05/17/2003.
- Onal, H., Algozin, K. A., Isik, M. 1997. Environment, Equity and Watershed Management. Paper presented at the American Agricultural Economics Association, Toronto, Canada; July 1997.
- Parks, R.W. (1980), "On the Estimation of Multinomial Logit Models from Relative Frequency Data", *Journal of Economics*, 13, 293–303.
- Phinn, S. and Stanford, M. 2001. Monitoring Land-Cover and Land-Use Change in a Rapidly Urbanizing Coastal Environment: the Maroochy and Mooloolah Rivers catchments, Southeast Queensland, 1988-1997. *Australian Geographical Studies*, 39(2): pp. 217-232.
- Reynolds, Johh, E. 2001. Land Use Change and Competition in the South. *Journal of Agricultural and Applied Economics*, 33(2): pp. 271-281.
- Reynolds, John E. 2000. Florida Rural Land: Competition Between Agricultural and Urban Uses. *Soil and Crop Science Society of Florida Proceedings* 59 (2000): pp. 94-98.

United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS). <http://nrcs.usda.gov>

United States Environment Protection Agency (USSEPA). <http://www.epa.gov/ost/>

Wear, D. W., and Bolstad, P. 1998. Land-Use Change in the Southern Apalachian Landscapes: Spatial Analysis and Forecast Evaluation. *Ecosystems* (1998) 1: pp. 575-594.

### Appendix 1. Land use reclassification scheme applied in the study

CLASS	DESCRIPTION	NLCD-92 Grid Code	CHOUSE-98 Grid Code
DEVELOPED	Low intensity residential	21	22
	High intensity residential	22	24
	Commercial/Industrial/Transportation	23	18
	Utility swaths	-	20
	Urban/Recreational Grasses	85	73
AGRICULTURAL	Pasture/Hay	81	80
	Row crops	82	83
FOREST	Transitional/Clearcut/Sparse	33	31
	Deciduous forest	41	41
	Evergreen forest	42	42
	Mixed forest	43	43
OTHER	Open Water	11	11
	Bare rock/Sand/Clay/Mud	31	07, 34
	Quarries/Strips/Mines/Gravel Pits	32	33