Integrating Land-Use Change Analysis and Ecological Risk Assessment

Tara A. Maddock, Ph.D and Michael Troyer, Ph.D.
U.S. EPA, National Center for Environmental Assessment, 26 W Martin Luther King Drive, Cincinnati, OH 45268; maddock.tara@epa.gov

EPA Science Forum 2004
Healthy Communities and Ecosystems

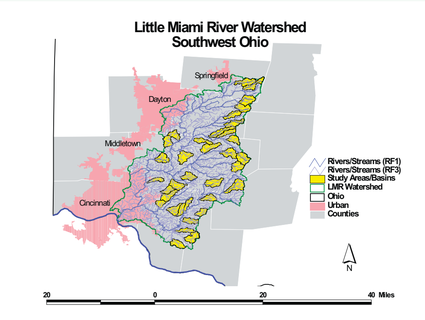
LAND COVER CHANGE, WATER QUALITY AND EPA RESEARCH

Nonpoint source pollution originating in water runoff from agriculture and urban land cover is now the largest threat to water quality. Surface water runoff contains excess sediments, nutrients, pathogens and pesticides that degrade water quality. Urban development increases the impervious surface (roadways, parking lots, and rooftops) in a watershed and quickly conveys pollutants to streams.

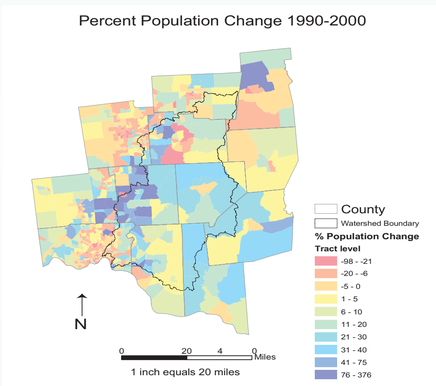
Urban development has serious and often irreversible impacts to water quality. Many of the environmental improvements over the past 30 years are jeopardized by sprawling suburban developments that encroach on farmland, pave over open space, and increase dependence on the automobile.

EPA recognizes these large impacts from suburban development and habitat degradation, but has little regulatory authority over these sources. Land use is managed and regulated by local jurisdictions such as towns, townships, cities, or counties. The EPA conducts research on land use and land cover change to assess risks to water quality, to support decision-making by regions, states and tribes, and to provide information to local jurisdictions and communities in making land-use decisions (US EPA Region 5, 2000).

STUDY AREA



The Little Miami River Watershed is predominately rural with rapid residential development in the northern and western portions of the watershed. The Little Miami River contains some of Ohio's most scenic and diverse river ecosystems and is a designated national scenic river. The high quality ecosystems and water quality are under severe stress from rapid land use/land cover change.



SPATIAL DIMENSIONS OF RISK TO WATER QUALITY

The impacts from land cover change are not spread evenly throughout the watershed (Wear, Turner and Naiman, 1998). Negative impacts from urbanization may be mitigated to a large extent by preserving or restoring habitat quality or by reducing multiple stressors.

Three factors of habitat quality are important in Ohio urban sites that are able to maintain relatively good water quality and aquatic biology (Miltner, White and Yoder, 2004):

1) Intact riparian zone vegetation
2) Undeveloped floodplains
3) Streams that receive significant amounts of groundwater

Protecting riparian areas and floodplains can reduce the risk of pollution impacts in rivers and streams in Ohio. In order to understand the risks, and to understand where land use change is likely to occur next, it is important to assess the social causal factors driving rapid suburban development. A better understanding of the human dimensions of land use change can be used to more effectively protect water quality and to direct development to minimize adverse impacts on economic activity, social equality, and natural resources.

LAND COVER CHANGE ANALYSIS

This research analyzes the relationship between socioeconomic factors (income, population growth, and economic sector activity) and land cover change patterns (urban, residential, agricultural and forest) using geographic information systems (GIS).

Using GIS to map and analyze spatial patterns is very useful for land use planning and management. The goal is to assess the current pattern of development and identify significant social processes and characteristics. This information can be used to direct development to less sensitive areas and protect riparian corridors.

©2003 Regents of the University of Minnesota. All Rights Reserved.
Used with the permission of Design Center for American Urban Landscape

IMPACTS OF SUBURBAN GROWTH ON THE ENVIRONMENT:

Land Cover Change Impacts:

- Watershed Hydrology
- Riparian Habitat
- Flow
- Nutrients
- Sediments

Water Pollution:
Urban development results in soil erosion, increased runoff, loss of wetlands, and degradation of riparian habitats that impacts both surface and ground water.

- Temperature
- Algal growth
- Low DO
- Toxics
- Pathogens

Water Quantity:
Increase in impervious surface and changes in watershed hydrology can lead to increased flooding levels and frequency of flood events.

Air Pollution:
More cars, driving further distances, with more congestion and emission of air pollutants.

Loss of Natural Areas:
Unwanted suburban growth into previous open or natural areas such as wetlands, prairies, and woodlands.

Brownfields:
Movement of industry and business from city centers to outer ring suburbs in search of cheap land and labor force, but often leaves behind abandoned and polluted sites known as brownfields.

Cost of Infrastructure and Services:
It is expensive to supply drinking water, sewers, stormwater retention and emergency services to suburban areas. Suburban development costs local governments $1.20 (average in Midwest) compared $1.00 in tax revenue generated.

Farmland:
Prime farmland is converted to suburban development increasing pressure to farm on marginal or natural habitat lands. The increase in impervious surface contributes to more pollution and flooding impacts than from farm land use (US EPA Region 5, 2000).

RESEARCH QUESTIONS

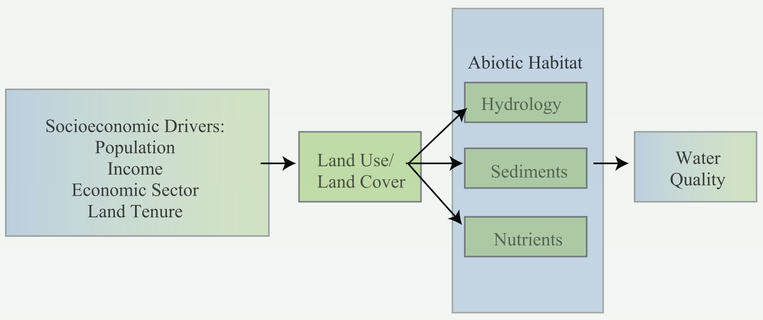
1. What is the spatial pattern and characteristics of land cover change in the Little Miami River Watershed from 1994 to 2002?

2. What are the significant socioeconomic characteristics associated with areas of land cover change?

3. Are there significant differences in the type of jobs located in 1) central business districts; 2) suburban and exurban residential areas; and 3) rural areas? What impact does economic sector activity have on land cover change?

METHODS

Using a watershed scale approach, the study uses geographic information system (GIS) and spatial analysis to integrate demographic and economic driving forces of land use/land cover change. GIS and remote sensing technologies are powerful tools for organizing and analyzing geo-referenced information about physical and human environments.



Land Cover Data:
1994 Land Cover. 30 m resolution. Source: Ohio Department of Natural Resources
2002 Land Cover. 4m and 30 m resolution. Source: US EPA

Socioeconomic Variables:

Population
Population, density
Population change
Age of Head of Household
Number of Children
Ethnicity, Native or foreign born

Income and Education
Education
Income, average by household
Poverty, public assistance by household

Economic Sector
Occupation, by residence
Employment by major economic sector (SIC code)

Land Tenure/Housing
Households
Length of residency
Own or Rent
Housing: age, type of unit, bedrooms, value
Public sewer/water; Septic, Well
Commute Time
Residential Building Permits

SPATIAL ANALYSIS WITH GEOGRAPHIC INFORMATION SYSTEMS:

- Land cover change 1994-2002, 30 m resolution
- Measure of Sprawl: Ratio of growth in population to growth in urban land area
- Residential housing density
- Distance of newly urbanized areas to city centroids
- Impervious Surface
- Road densities

REGRESSION ANALYSIS:

Multivariate Regression Model:

$$LC = P + I + ES + LT$$

Dependent Variable: LC = land cover change 1994 to 2002

Independent Variables: Socioeconomic Data

The socioeconomic data will be reduced to four factors produced from Principal Components Analysis:

P = Population variables
I = Income and Education variables
ES = Economic Sector data.
LT = Land Tenure

CONTRIBUTIONS OF RESEARCH

The research illustrates how social factors and patterns of land use/land cover change can exacerbate or mitigate an area's susceptibility to environmental degradation. The U.S. EPA recognizes the importance of incorporating spatial-temporal analysis, human dimensions of environmental management and communication with stakeholders in decision-making processes (Gilman, 2003). Researching the social and economic drivers of land cover change will provide an understanding of the risks to water quality from rapid urbanization.

Spatial analysis of social and landscape variables in a GIS can aid in identifying:

1) rate, location, and social drivers of land use change

2) impacts to water resources

3) impacted populations and interested stakeholders.

The results of the analysis will inform state and tribal regulators, watershed managers, and communities on the risks to water quality from land use change. Further, the results can be used to point to non-regulatory or voluntary measures that communities can take to direct land use and protect water resources.

References:
Gilman, P. 2003. Research paves paths to sustainability. National Council for Science and the Environment's Third Annual Conference on Science, Policy and the Environment. Available: www.ncseonline.org.

Miltner, R., D. White, and C. Yoder. 2004. The biotic integrity of streams in urban and suburbanizing landscapes. Forthcoming in Landscape and Urban Planning.

US EPA Region 5. 2000. Environmental quality and community growth. EPA/905/F-00/003. U.S. Environmental Protection Agency, Chicago.

Wear, D., M. Turner, and R. Naiman. 1998. Land cover along an urban-rural gradient: implications for water quality. Ecological Applications 8(3): 619-630.