Simulating Urban Growth on the Web

Jay Lee, Thomas M. Brody, Rick Zhang, Hyun-Joong Kim, and Mark Bradac

Rising concerns about urban sprawl have prompted the Applied Geography Laboratory at Kent State University, in conjunction with the EPA, to develop a Web GIS–based urban-growth simulator. With data for 15 Ohio counties, the tool proved so useful that AGL is now offering a free standalone version for use in any community.

Throughout the United States, sprawling developments are quickly converting open space and rural areas into low-density residential, commercial, or industrial uses. This phenomenon is often referred to as urban sprawl because of its haphazard pattern of growth. Although some argue that sprawling growth of urbanized areas may have potential long-term economic benefits, it is evident that fast-paced urban growth brings many immediate problems to local communities. These problems include using land and energy inefficiently, increasing traffic congestion and pollution, damaging environmentally sensitive areas and open space, and even losing the characteristics of local communities.

The affects of urban sprawl and growth are so pressing that, according to the Pew Center for Civic Journalism (www.pewcenter.org, a non-profit, non-partisan group offering content and surveys to news organizations), Americans now rank sprawl as important as urban crime. And communities are now joining planners, public officials, environmentalists, and other concerned citizen groups to evaluate and seek ways to improve land-use decisions.

To help manage urban growth at the community level, Kent State University's AGL developed a GIS-based, community-accessible urban sprawl impact assessment tool for a 15-county region in Ohio. Commissioned by the Northeast Ohio EMPACT project (http://empact.nhlink.net) as part of the U.S. EPA's nationwide EMPACT program, the site was deployed in early 2002. It allows citizens to interactively define parameters for modeling growth. The site has proved so popular, even beyond the boundaries of the 15-county area in Ohio, that the AGL has made a standalone version of the simulator available so that other GIS professionals and public agencies throughout the United States can integrate their own city or county data with the program.

Glossary

AGL: Applied Geography Laboratory

EMPACT: Environmental Monitoring for Public Access and Community Tracking

EPA: Environmental Protection Agency

MAGIC: Map and Geographic Information Collection

NOACA: Northeast Ohio Areawide Coordinating Agency

Building out

Communities typically rely on comprehensive (or master) planning to help them avoid random and undesirable growth. Comprehensive planning depicts how a

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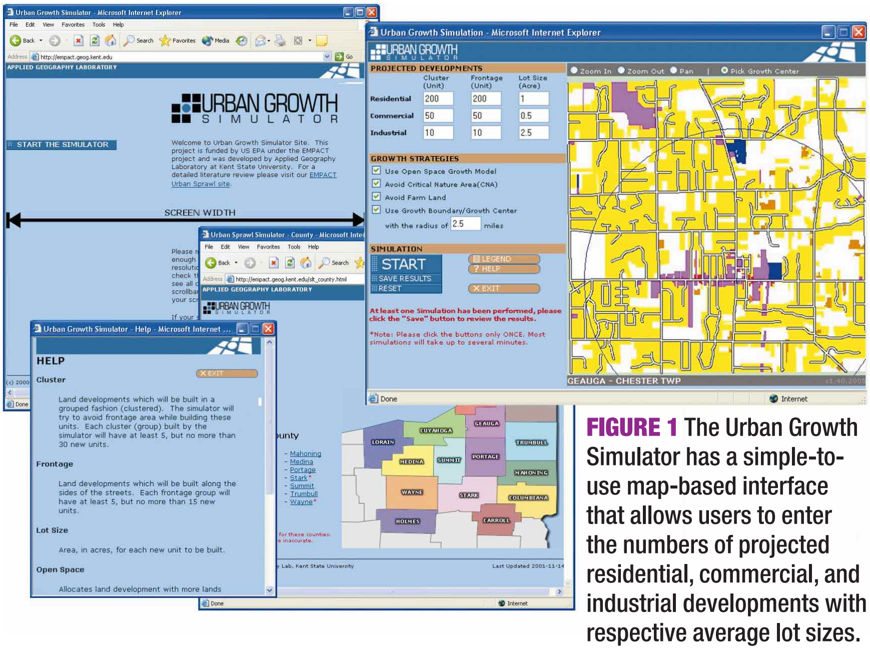

FIGURE 1 The Urban Growth Simulator has a simple-to-use map-based interface that allows users to enter the numbers of projected residential, commercial, and industrial developments with respective average lot sizes.

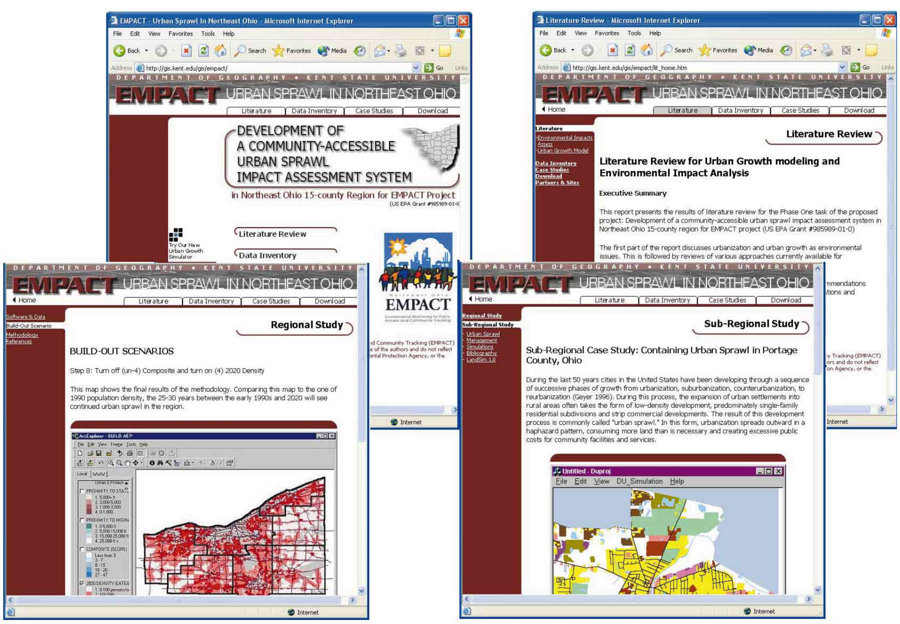

FIGURE 2 A complementary Web site contains information about urban sprawl in the context of the local communities in Ohio. The site contains a comprehensive literature review of currently available computerized urban-growth modeling techniques and environmental impact assessment methods as well as two case studies with example build-out scenarios.

community will develop under current land-use policy and predicts future changes. To help the general public understand the essence of the plan, maps showing build-out scenarios are often produced to graphically illustrate projected outcomes under the comprehensive plan.

The generation of build-out scenarios, though, is a tedious process because it requires large volumes of data, assumptions about future changes, laborious calculations, and arduous map creation. The proliferation of GIS has streamlined the generation of build-out scenario maps and computerized simulation of urban growth, but the technology's sophisticated analytical functions require a professional-level skill set, especially for managing and integrating the large amounts of data necessary for urban-growth modeling.

With ease of use in mind, the Kent State AGL designed the Urban Growth Simulator (accessible at http://empact.geog.kent.edu) to be simple to employ and understand by citizens of all ages and backgrounds.

The Urban Growth Simulator allows users to generate build-out scenarios at township, village, city, county, and regional levels within the 15-county area of Northeast Ohio. It has a simple-to-use graphical user interface with straightforward representation of land-use patterns, and a PDF instruction manual is downloadable from the site (see Figure 1).

The AGL also developed a complementary Web site for the Northeast Ohio EMPACT project (see http://gis.kent.edu/empact) with information about urban sprawl in the context of local communities (see Figure 2). In addition, the site contains a comprehensive literature review of currently available computerized urban-growth modeling techniques and environmental impact assessment methods. Also included are two case studies that citizens can browse to see examples of build-out scenarios: one for regional patterns and another for countywide patterns.

An iterative process

The Urban Growth Simulator relies on an iterative model to develop as much simulated growth as possible within user-specified parameters. Users are expected to enter the numbers of projected residential, commercial, and industrial developments with respective average lot sizes in the community. They can also partition projected growth along either road frontage or clusters.

With user inputs defined, the model commences by randomly selecting a location for development. It tests to see if the selected location satisfies all the requirements set by the user's specified growth management strategies. If the point passes all the tests, the Urban Growth Simulator checks the zoning code of the area and chooses the actual size of the development. Once a parcel is marked developed or infeasible for development, the program iterates the same process for other locations until the specified area is built out according to the user-selected growth management restrictions.

When the simulation is complete, the Urban Growth Simulator returns and displays a map to the user showing new

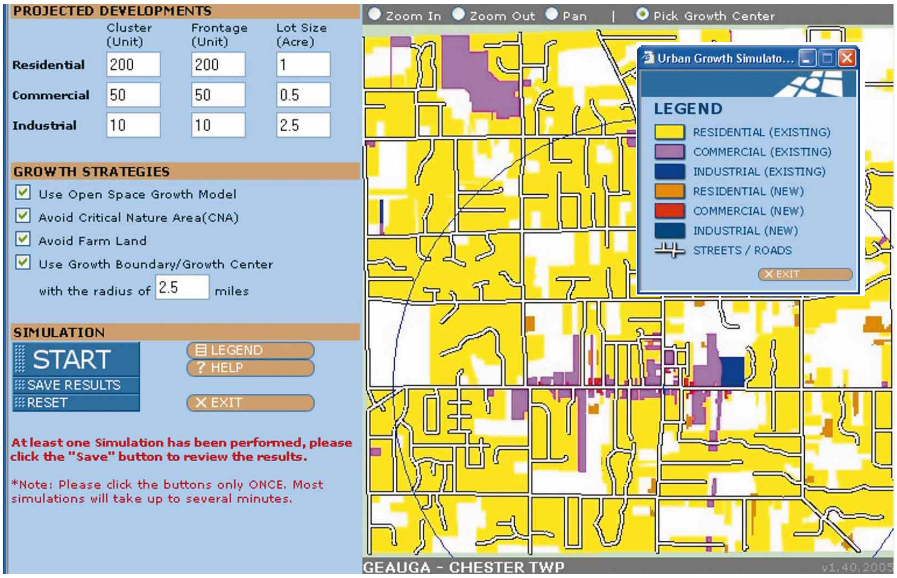

FIGURE 3 When the simulation is complete, the site returns a map showing new development along with existing land uses. In addition, a map legend and help button assist users in understanding the displayed map. In this example, brown patches denote simulated residential land use, and yellow patches indicate current residential land.

Statistics (GEAUGA - CHESTER TWP)

Land Use (actual/projected)

Type	Cluster	Frontage	Lot Size	Sub-Total
Residential	100/100	100/100	1	200/200
Commercial	20/20	20/20	0.5	20/20
Industrial	10/10	0/10	2	20/40
			Total Acres	**240/260**

Agricultural Land Lost 0 acres.
Critical Nature Area Lost 0 acres.
Open Space: ON **Avoid CNA:** Yes **Avoid Farm Land:** Yes **Boundary:** Yes

Download Shape Files

Click on following links to download shape files for this simulation:
Simulated Layer: [*.shp] [*.shx] [*.dbf]
Other Layers: LandUse/Zoning/CNA/Streets
DevCode in Simulated Layer: 11=Residential, 12=Commercial, 13=Industrial
Projection: Stateplane Projection, North Ohio Zone, Datum NAD83.

RESET Calculate Hydrosoil Usage

FIGURE 4 Users can have the Urban Growth Simulator calculate how many acres of critical natural areas and farmland are lost due to estimated development. The simulator presents these findings in a simple numerical table. The site also presents an option for downloading results in shapefile format for integration with a desktop GIS for further processing.

development along with existing land uses (see Figure 3). The program also includes a map legend and a help button to assist users in understanding the displayed map. Figure 3, for instance, shows an output from the simulator with brown patches denoting simulated residential land use and yellow patches indicating current residential land.

Assembling data

Supporting the simulator are several data layers compiled from such sources as NOACA's MAGIC 2001 GIS data CD. NOACA, a regional planning agency for the Cleveland metropolitan area, compiled the MAGIC CD to integrate and share GIS data across seven of the counties in Northeast Ohio. NOACA also provided demographic projections and boundary files for portions of the project area. The Akron Metropolitan Area Transportation Study provided similar data for two other counties.

The Kent State AGL also assembled and digitized numerous other data layers for the Urban Growth Simulator. These data include 1990 Census population counts for all 15 counties, state highway routes from the Ohio Department of Transportation, and Census TIGER/Line files showing limited access highway interchanges.

The simulator uses all the demographic and transportation data in conjunction with a data layer indicating zoning districts to determine lot sizes for simulated development. In addition, a data layer of agricultural lands for the region is used to determine the acres of farmland in the simulated development. It overlays agricultural lands with the simulated development to project the number of farmland acres lost.

Because environmental impact assessment is an important issue for the Northeast Ohio EMPACT project, another important data layer shows critical natural areas, including steep slopes, floodplains, wetlands, and places having federal- and state-designated threatened or endangered species. The AGL compiled and digitized the environmental layer from Landsat imagery as well as incorporated data from the Ohio Department of Natural Resources and Cleveland MetroParks. The simulator handles the environmental layer in the same way as the farmland data — overlaying projected development results on the data to determine the extent of critical natural area loss.

Growth models

To better approximate a community's comprehensive plan, the Urban Growth Simulator offers several tools for manipulating the data following different growth management strategies. For example, the site enables users to model future growth with an emphasis on preserving open space. This option cuts down the lot size of clustered residential units so that less open space is used to house low-density residential developments.

Another commonly adopted growth management strategy is to limit development to within a designated area by implementing a growth boundary. As such, the Urban Growth Simulator allows users to define the radius of a circular growth boundary. This option typically ensures more compact simulated growth

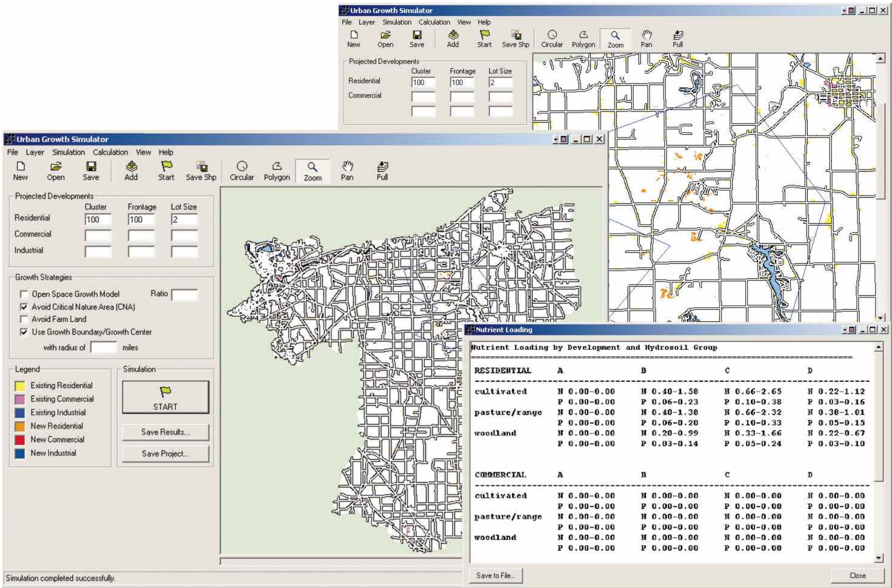

FIGURE 5 A standalone version of the Urban Growth Simulator preserves all the functions and user interface of the Web version, and includes a function for estimating nutrient loadings resulting from simulated development.

than the random, unrestrained sprawl of haphazard development.

For environmental protection, users can also instruct the simulator to protect critical natural areas. With this option, locations zoned for development will be abandoned as undevelopable if the simulator finds them to be among steep slopes, floodplains, wetlands, or areas with endangered or threatened species.

The final output

After each model-generation, users can have the Urban Growth Simulator calculate how many acres of critical natural areas and farmland are lost due to estimated development. The simulator can present these findings in a simple numerical table (see Figure 4), which provides users with valuable data for incorporating into environmental impact assessments.

Users can also output the simulator results and maps in shapefile format. This enables simulated results to be imported into popular GIS products for further processing and analysis.

A standalone version

By using different combinations of projected growth and growth management, the Urban Growth Simulator gives users a tool to vividly discover the effectiveness of their comprehensive planning. For example, the Portage County Regional Planning Commission successfully used the Urban Growth Simulator to generate build-out scenarios based on different sets of land-use policies. The resulting maps are being circulated among townships and at public meetings for citizen input and comments. Similarly, Geauga County Planning Commission is using the simulator to fine-tune their land-use policy and assist with several watershed management and riparian protection plans.

The Urban Growth Simulator has also proved to be very popular beyond the 15-county region of Ohio that its datasheet covers. After the inception of the simulator Web site, the Kent State AGL received numerous requests to revise the Urban Growth Simulator so that it could be used with other data. In responding to these requests, the lab developed a standalone version of the program (see Figure 5). The standalone version preserves all the functions and user interface of the Web version and includes a new function that estimates nutrient loadings due to simulated development. These newly added functions allow users to further examine how the simulated growth impacts their community's environment beyond the loss of farmlands and critical natural areas.

From Kent State AGL's perspective, the development of the Urban Growth Simulator was only a small portion of the entire project when compared with the effort to assemble the required data. But making the program available to other agencies and organizations can help them implement their own simulator for managing urban growth. Interested parties can request the standalone version of the program from ksuagl@kent.edu.

Manufacturers

Kent State AGL coded the Urban Growth Simulator's simulation engine in Visual Basic with functional calls from MapObjects 2.1 and MapObjects IMS, both from **ESRI** (www.esri.com). The simulator resides on a Web server running Microsoft's Windows 2000 Advanced Server. The U.S. EPA provided the funding for the project. 🌐