

An Internet-based Urban Growth Simulator: Its implementation and application

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Abstract: Developed for Internet-based simulations, the Urban Growth Simulator allows users to select from a suite of available options for growth management when generating build-out scenarios. With all required data layers for the 15-county region in northeast Ohio freely accessible and available from the simulator's server, planners, government officials, and the general public can use the Urban Growth Simulator to examine how their communities are to be affected by potential growth. With generated build-out scenarios, the Urban Growth Simulator also performs calculations for estimating environmental impacts due to simulated growth.

The Urban Growth Simulator was developed by using a combination of codes in Visual Basics with MapObjects and functions in ArcIMS. The implementation of the simulator demonstrates the versatile capability of combining MapObjects and ArcIMS. In addition to county-level planning agencies, the Urban Growth Simulator is being used to support a watershed management project for Grand River, also in Northeast Ohio.

Key Words: Urban growth, Simulation, Internet GIS

1. INTRODUCTION

Urban growth is a global phenomenon that comes with the advancement of technology and evolution of civilization in all cultures. A growing city offers many conveniences, employment opportunities, and amenities to its residents that are not always available in rural areas. At the same time, a growing city faces many obstacles that may limit or hamper its sustainability. Therefore, effective urban planning and management with a goal of long term sustainability become essential for a healthy city.

2. THE NORTHEAST OHIO URBAN SPRAWL WEB SITE

Decisions on how to effectively plan and manage urban growth are often difficult because of the complexity and longevity of urban development. As such, researchers and practitioners have developed a number of urban growth models trying to best approximate the urbanization process. Among 10 such models reviewed for controlling urban sprawl in northeast Ohio in the United States, the Portage County model was used as the basis for developing an Internet-based urban growth simulator. The review of urban growth models and other literature information can be accessed at http://gis.kent.edu/gis/empact/lit_home.htm. This review evaluates up to 10 different urban growth models with respect to whether they can be applied in the context and condition in Northeast Ohio. The consideration also includes the availability of data required by each urban growth model. In Northeast Ohio, some counties have more extensive collections of digital data while others lack such resources. As a result, the Portage County buildout scenario was recommended because the data layers it requires

are available for all 15 counties in the region. While other urban growth simulators may be more comprehensive or versatile in their functions, not all data layers are available for all counties to make them work in the region.

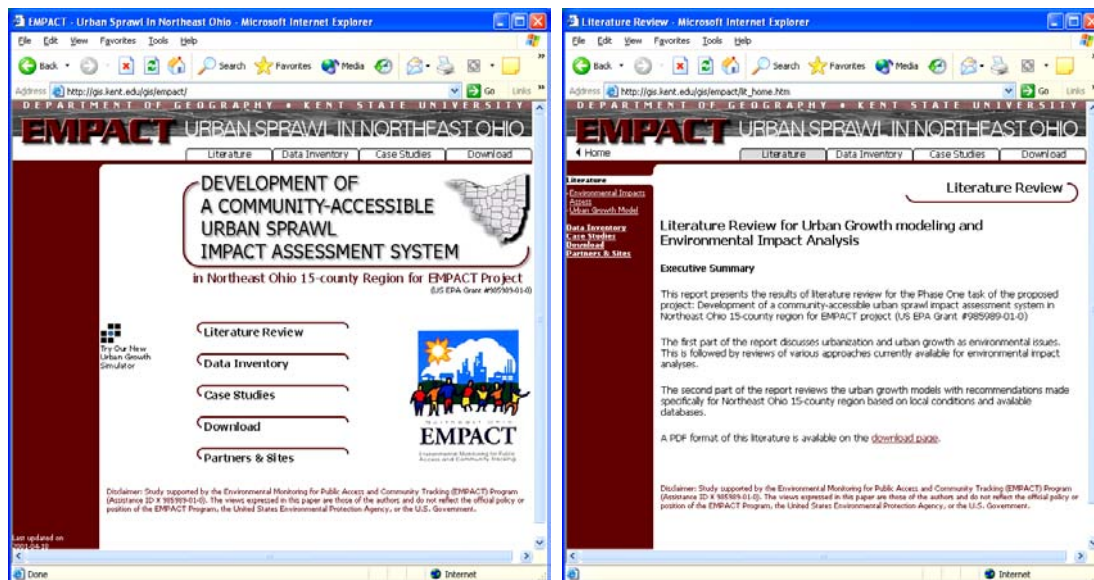


Figure 1: Northeast Ohio Urban Sprawl Web Site.

In addition, the Northeast Ohio Urban Sprawl web site hosts links to NEOEDEN, a web site for NorthEast Ohio Environmental Data Exchange Network that provides extensive information on environmental data for the region. Finally, the Northeast Ohio Urban Sprawl web site also showcases two case studies: a regional study for the sustainable development in the 7-county region and a sub-regional study for Portage County regarding its land use planning.

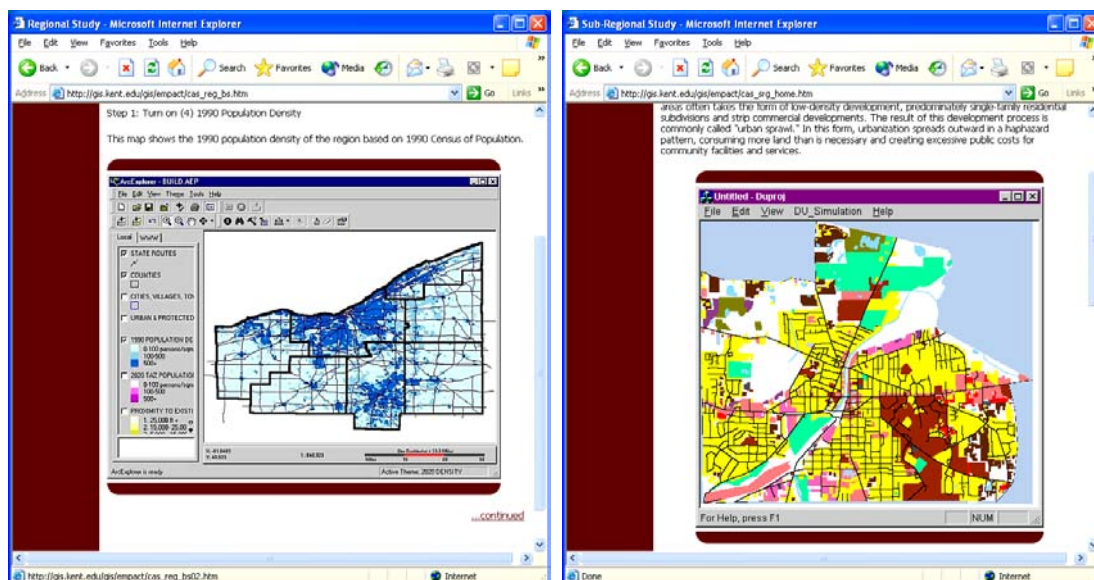


Figure 2: Regional case study (left) and Sub-regional case study (right).

After the inception of the Urban Sprawl web site for Northeast Ohio, it was recommended that a GIS- and web-based tool be developed to allow everyone an easy way to generate buildout scenarios. It was also recommended that this simulation tool include some options for emulating strategies typically

used by planners in controlling urban growth. The purpose of developing such a tool is to allow any users, albeit governmental officials or local interest groups, trained land use planners or average citizens, highly skilled analyst or school children, to be able to generate buildout scenarios for their own communities easily and meaningfully.

3. URBAN GROWTH SIMULATOR

Funded by the US Environmental Protection Agency under the Environmental Monitoring for Public Access and Community Tracking (EMPACT) program, Kent State University's Applied Geography Laboratory (ksuagl@kent.edu) has developed a GIS- and web-enabled Urban Growth Simulator (UGS), accessible at <http://empact.geog.kent.edu>. The entry page to UGS is shown in Figure 3 below.

Using this simulator, urban planners, concerned interest groups and the public can view how their community will grow by simulating urban growth to generate buildout scenarios. In addition, this simulator allows users to incorporate various growth management strategies. Finally, the simulator calculates the impact to the community's environment caused by the simulated growth.

Upon entry, UGS provides both a graphic interface and links for users to select local communities for further simulations. Local communities are the sub-county political units such as townships, villages and cities. Once a local community is selected, UGS turns to its main environment for simulation. In this environment, UGS provides tools for users to zoom in/out as well as panning the mapped area in the web browser. For inputs to simulations, UGS expects users to enter the number of units projected for future growth. These projected growths as displayed in units and can be separated into residential, commercial, and industrial land uses. Furthermore, the projected growths can be specified as clustered developments or developments along road frontages. Each unit is related to an average lot size for actual implementation during simulations.



Figure 3: Entry page of the GIS- and web-based Urban Growth Simulator

In Figure 4, UGS is shown with four growth management strategies all enabled. It also has links to start simulations, to zoom in/out and to pan the map area, to define the center for a growth boundary, to save results, to show legend keys for colors used in the maps, to get help, and to exit from the program.

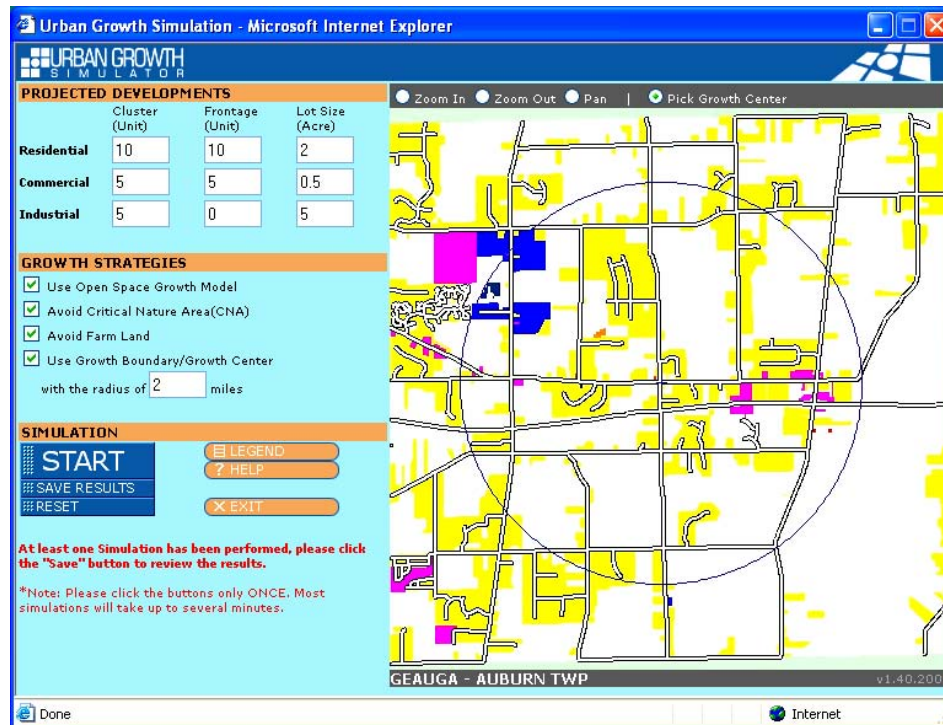


Figure 4: Simulation tools and growth management strategies in Urban Growth Simulator.

UGS allows user to select and implement any combination of growth management strategies. For example, Figure 4 shows that the buildout scenario to be generated is using an implementation of Open Space design, avoidance of development in critical natural areas, avoidance of development in prime farmlands, and a circular growth boundary with a 2-mile radius surrounding the user-selected growth center.

Once the buildout scenario is generated, UGS displays simulated developments in map form. The results of the simulation can be saved in two ways: as ArcView Shapefiles and as a tabulated summary. Figure 5 shows an example of a tabulated summary as outputted from UGS. It shows the implemented growth management strategies as well as the numbers of acres of land used by the simulated development. In this page, UGS also provides links for users to download shapefiles that contain the simulated development for further mapping with GIS software.

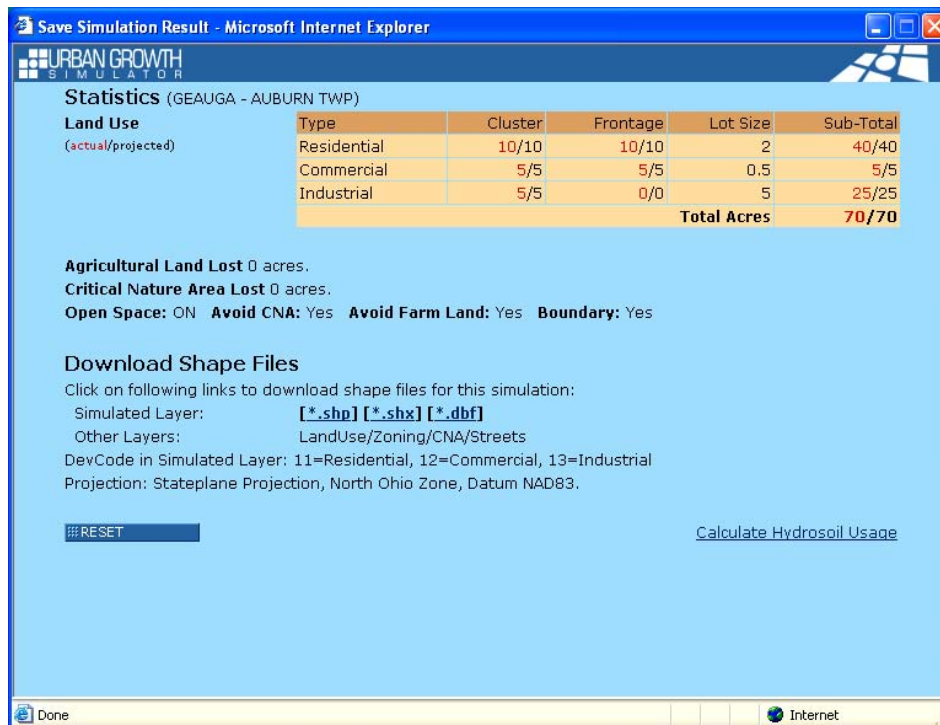


Figure 5: Tabulated output from UGS

ArcView shapefiles can be generated and incorporated with other data layers to design elaborated maps. A tabulated summary provides detailed accounts of the number of acres of land used by the simulated development, based on user-specified growth projections. Additionally, a tabulated summary also lists the number of acres of critical natural areas and farmlands lost to simulated development.

Finally, UGS includes a link for users to calculate hydrosol usage. When this link is clicked, UGS overlays simulated land development over a data layer of hydro soil groups. The results of this overlay can be used to estimate environmental impacts as caused by simulated development. Via equations listed in the EUTROMOD model (Haith and Shoemaker 1987), the results of overlaid acres of hydrosol groups are used to estimate the amount of nutrient loadings added to the environment by the simulated development. These estimated nutrient loadings are expressed as Nitrogen and Phosphorus in kg/year.

UGS has two versions. The web version is executable over Internet with all datasets for the 15-county region in northeast Ohio. The stand alone version can be used with datasets users assemble for their own communities. The Urban Growth Simulator can be accessed freely over Internet. For the stand alone version, the simulator can be requested from the Applied Geography Laboratory at Kent State University via email at ksuagl@kent.edu.

4. DATA PREPARATION

The stand alone version of the UGS can be used for a myriad of applications. However, there are certain procedures that must be followed in order to prepare data before using them as inputs to the UGS. This mostly involves recoding the data tables in a GIS software package such as ESRI's ArcGIS. Also – depending on the application – some data may need to be created first using both GIS and Remote Sensing software.

The UGS uses strict naming conventions in order to accurately read the requisite data. The various shapefiles must be placed in a common directory exclusively using the following names: landuse.shp for Land Use/Land Coverage, streets.shp for Streets/Roads, zoning.shp for Zoning, cna.shp for Critical Nature Area (CNA), water.shp for Water Layer, and soil.shp for Soil Layer. Any layers not adhering to these naming conventions will be ignored by UGS during the pre – processing stage, which will have detrimental effects on the results.

In terms of coding, the data tables of the input shapefiles must have fields added that are used by UGS to make determinations during simulations. This editing is usually accomplished using one of ESRI's software packages such as ArcView or ArcGIS. However, this editing could also be accomplished using a standard spreadsheet program. Table one shows the requirements for coding of the main input data files to UGS.

Table 1: Urban Growth Simulator Field Classification

Layer	Field Name	Field Length	Value	Description
Land Use	UGS_LU	4	0	Developable
		4	1	Un-developable
		4	11	Residential
		4	12	Commercial
		4	13	Industrial
	UGS_AG	4	0	Non-agriculture
		4	1	Agriculture Land
Zoning	UGS_ZO	4	0	Other Zones
		4	1	Un-Zoned (Developable)
		4	10	Residential (Low Density, over 1 Acre/DU)
		4	11	Residential (Medium Density, 0.2-to-1 Acre/DU)
		4	12	Residential (High Density, below 0.2 Acre/DU)
		4	20	Commercial
Soil	UGS_SO	16	<i>string</i>	Hydrosoil types
	UGS_SN	4	1-Max	Hydrosoil type index number, unique (from 1 to max)
	UGS_HG	1	<i>string</i>	Hydrosoil group

The preparation of a riparian corridor within a Land Use/Land Coverage data file involves some minor manipulations to be made to the source data. This can easily be accomplished using the Geoprocessing Wizard and Buffer Wizard in either ArcView or ArcMap. After creating and saving the desired width buffer, the user must then union the buffered layer and the Landuse layer. Once this is accomplished the user must select all the UGS_LU = 0 (developable) areas and BUFFERDIST = DISTANCE (selected buffer width). The final step involves opening the attribute table, choosing “calculate values” for the UGS_LU field, and using the field calculator to change the selected values to 1 (undevelopable). This will results in riparian corridor areas within the Landuse layer that will be read by UGS as undevelopable.

In some cases it may be desirable to use a classified satellite image as the basis for the Land Use/Land Coverage data. Of course, the actual classification must be carried out using a separate software package such as PCI or ERDAS and then converted into an ESRI shapefile. After this has been accomplished the user must then add the appropriate fields and code them according to the aforementioned naming conventions. As far as what portion of the image should be classified as Undevelopable, Developable, Farmland, CNA, Water, etc. will depend somewhat on the classification methods used. An example might be by classifying the image into categories such as water, urban, residential vegetation, farm vegetation, forest, and other. For this example the user might recode the

water, and other as undevelopable (code = 1). Then the user might recode the urban and residential vegetation as residential (code = 11) and the forest as developable (code = 0). For the farm vegetation category the user might code the UGS_LU as developable (code = 0) and the UGS_AG as undevelopable (code = 1). Using a satellite image as the land use input has several advantages. This could include the lack of reliable land use data for a selected location.

5. AN EXAMPLE APPLICATION

UGS has been used by a number of local planning agencies for detailed, long term land use planning. One of these projects is the land use planning in Geauga County Ohio. The Geauga County Planning Commission projected growth for its 22 communities according to those listed in Table 1 below.

Table 2: Projected Residential Building Permits to 2020

Building Permit Projections	
<u>Communities</u>	<u>Projection to 2020</u>
Aquilla Village	10
Auburn Township	1,065
Bainbridge Township	1,580
Burton Township	305
Burton Village	50
Chardon Township	730
City of Chardon	432
Chester Township	1,075
Claridon Township	325
Hambden Township	545
Huntsburg Township	365
Middlefield Township	335
Middlefield Village	148
Montville Township	345
Munson Township	1,060
Newbury Township	730
Parkman Township	390
Russell Township	635
South Russell Village	232
Thompson Township	250
Troy Township	240
Totals	10,577

Source: Geauga County Building Department 2002

Using the projected growth listed in Table 1, simulations were carried out to generate buildout scenarios for these communities. It was found that the Open Space design proves to be the most effective strategy for growth management.

To exam how riparian corridors may be used to assist land use planning and to assist the formulation of land use policies, two buffers (75 feet and 300 feet) were implemented around the streams in the county. For each local community, simulations were carried out with the following choices of growth management strategies: NoOp (no strategy used), Ops (Open Space design), Cna (avoiding critical natural areas), Farm (avoiding prime farmlands), OpsCna (Ops and Cna), OpsFarm (Ops and Farm), CnaFarm (Cna and Farm), and OpsCnaFarm (Ops, Cna, and Farm).

As shown in Table 2, the combination of using an open space design with avoidance of critical natural areas and prime farmlands turns out to be the best growth management strategies for many communities. This is true even with the implementation of riparian corridors. Open Space design alone, is also the best choice for many local communities, or as part of the solutions.

Table 3: Best Growth Management Strategies by Simulated Results

		No Buffer	75 ft Riparian Buffer	300 ft Riparian Buffer
Loss to: Residential Development	Community	Ops	Ops	OpsFarm ¹
	Auburn Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Bainbridge Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Chester Township	OpsCnaFarm	OpsCnaFarm	OpsCna
	Russell Township	OpsCna	OpsCna	OpsCna
	S Russell Village	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
Loss to: Farmlands	Community	OpsCna	OpsCna	OpsCna
	Auburn Township	OpsCna	OpsCna	OpsCna
	Bainbridge Township	Ops	Ops	Ops
	Chester Township	OpsCna ¹	Ops	Ops
	Russell Township	Ops	Ops	Ops
	S Russell Village	Cna	Cna	Cna
Loss of Cna	Community	OpsFarm	OpsFarm	OpsFarm
	Auburn Township	OpsFarm	OpsFarm	OpsFarm
	Bainbridge Township	Ops ²	OpsFarm	OpsFarm
	Chester Township	Ops	Ops	Ops
	Russell Township	Ops	Ops	Ops
	S Russell Village	OpsFarm	OpsFarm	OpsFarm
Nutrient Loadings (N)	Community	Ops	Ops	Ops
	Auburn Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Bainbridge Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Chester Township	OpsCnaFarm	OpsCnaFarm	OpsCna ³
	Russell Township	OpsCna	OpsCna	OpsCna
	S Russell Village	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
Nutrient Loadings (P)	Community	OpsFarm ¹	Ops	Ops
	Auburn Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Bainbridge Township	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm
	Chester Township	OpsCnaFarm	OpsCnaFarm	OpsCna ³
	Russell Township	OpsCna	OpsCna	OpsCna
	S Russell Village	OpsCnaFarm	OpsCnaFarm	OpsCnaFarm

¹ Ops is a close second, ² OpsFarm is a close second, ³ OpsCnaFarm is a close second

6. IMPLEMENTATION ISSUES

Throughout the course of several separate implementations of the UGS there have been different issues that have needed corrective measures. One of these is caused by the nature of the grid method UGS uses to create growth areas. Because UGS builds in an area following a grid pattern, build out locations on developable areas that have boundaries contiguous with undevelopable areas may experience some overlap of the results into undevelopable areas. This effect can be seen in figure 6 below. The magnitude of this problem will differ depending on the cell size used to perform calculations in UGS.

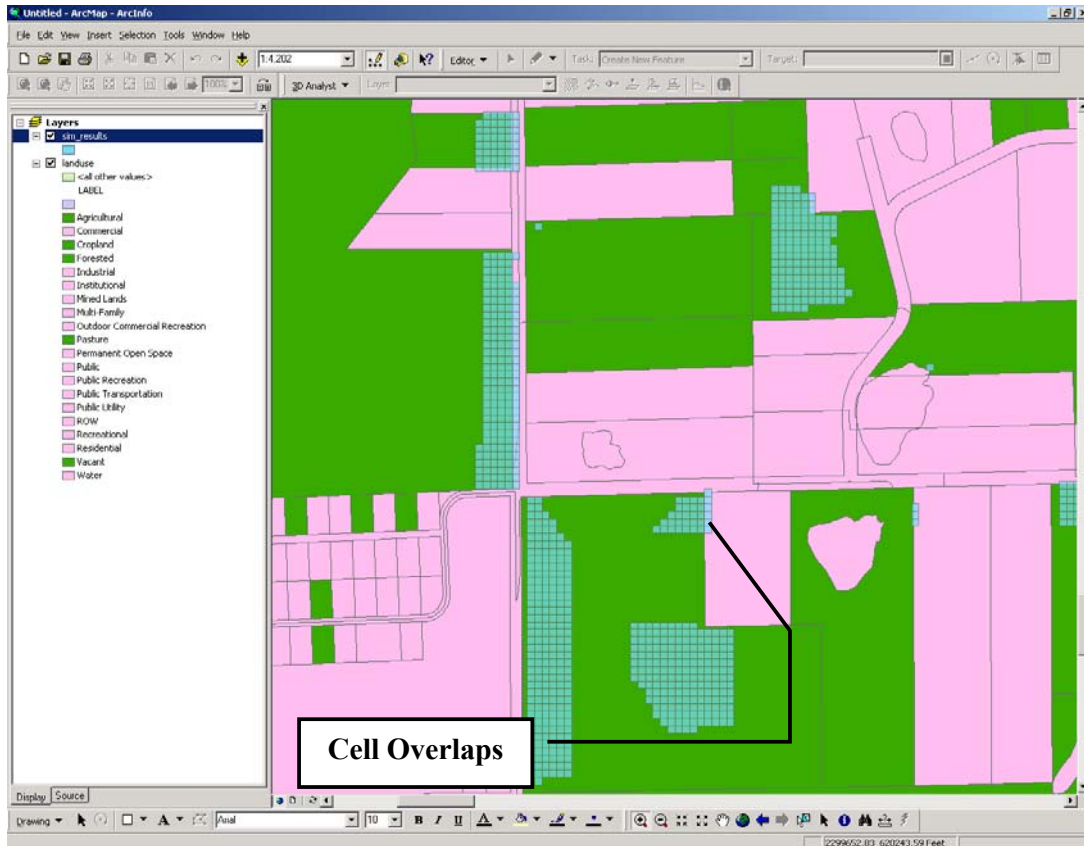


Figure 6: Cell overlaps from UGS

A series of steps has been developed to solve this problem and is conducted within either ESRI's ArcView or ArcMap software package. After adding the Landuse and simulation result shapefiles to the appropriate GIS the user should use the method outlined below to eliminate the cell overlaps.

1. Open the Geoprocessing Wizard and choose "Union".
2. Union the simulation results with the landuse layer. Under "1) Input theme to union" choose **simulation layer**; Under "2) Select polygon overlay theme to union" choose **landuse layer**.
3. Add the union results to the view, turn it on, and open the table.
4. Use the Select By Attributes Wizard to select all that are: ("DevType" = '11' AND "UGS_LU" <> 1) AND ("DevType" = '11' AND "UGS_LU" <> 11) AND ("DevType" = '11' AND "UGS_LU" <> 12) AND ("DevType" = '11' AND "UGS_LU" <> 13). This equation should be one continuous string i.e. double click devtype, then =, then "11" and so on. After the equation is built, make sure you are using the "Make a new selection" method and click "Apply" (see figure 7). This will highlight all of the areas that did not overlap into

undevelopable parcels (see figure 8). Therefore, all of the areas where unwanted overlap occurred (i.e. areas with ugs_lu codes of 1, 11, 12, and 13) will not be highlighted and will be eliminated from the final shapefile in the next step.

Select By Attributes

?

×

Query Wizard...

Layer:

Union_Output

Method :

Create a new selection

Fields:

"DevType"

"LABEL"

"TOWNSHIP"

"RS_CODE"

"CODE96"

"UGS_LU"

"UGS_AG"

"AREA_"

"PERIMETER_"

=

< >

Like

>

> =

And

<

< =

Or

_ %

()

Not

SQL Info...

Unique values:

0

1

11

12

13

Complete List

SELECT * FROM Union_Output WHERE:

("DevType" = '11' AND "UGS_LU" <> 1) AND ("DevType" = '11' AND "UGS_LU" <> 11) AND ("DevType" = '11' AND "UGS_LU" <> 12) AND ("DevType" = '11' AND "UGS_LU" <> 13)

Clear

Verify

Help

Load...

Save...

Apply

Close

Figure 7: Selection parameters.

Attributes of Union_Output						
DevType	LABEL	UGS_LU	UGS_AG	TOWNSHIP	RS_CODE	CODE96
11	Vacant	0	0	Auburn	0	
11	Vacant	0	0	Auburn	0	
11	Vacant	0	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Public Transportation	1	0	Auburn	0	
11	Vacant	0	0	Auburn	0	

Record: 1

Show: All Selected

Records (18570 out of 25100 Selected)

Options

Figure 8: Table selection results.

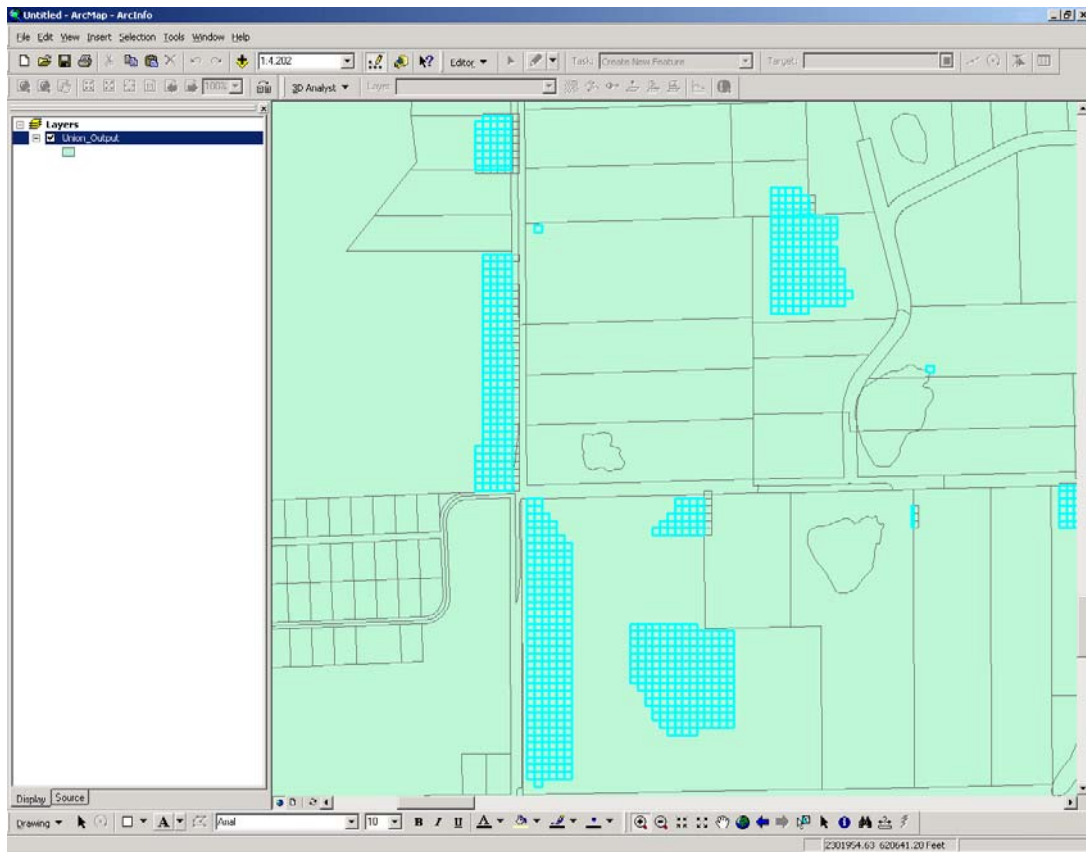


Figure 9: Results from eliminating overlaps

5. Save the selected grids as a new shapefile by right clicking the shapefile in the table of contents and choose “Data” – “Export Data” and save the selected features as a new shapefile. If you add the new shapefile to the view and display it over the merged output you can see how the result compares with the original simulator output (figure 9).

Another issue that occurred during the Geauga County project concerned the simulator building into water body areas. This generally occurs due to two reasons, first a small water body within a parcel marked as developable, and secondly a water body that stretches across parcel boundaries that are marked as developable and undevelopable respectively. Since the water layer is only used for display purposes by UGS, a water body meeting the aforementioned criteria will be built on during the simulation runs.

A simple solution has been developed using ESRI’s GIS software packages. The user has the option of either ArcView or ArcMap to implement this solution. It involves completing a union of the water and landuse layers with the Geoprocessing Wizard. Then both the developable areas and water areas are selected and recoded as undevelopable via the method described for the overlap solution. After this is completed the selection is converted to a shapefile and merged with the original landuse layer using the original landuse file fields.

In the future it is hoped that the UGS program will be reworked to include automated tools for accomplishing these two tasks as well as some others not described here. However, these two solutions are quit simple for any user familiar with GIS concepts and ESRI tools. This of course is somewhat expected since the stand alone version of UGS is designed primarily for those individuals familiar with such concepts.

7. CONCLUSIONS

While this paper presents only brief descriptions of some of the functions available in UGS, it can be seen that such a tool does provide a feasible approach to generating useful buildout scenarios that show how the future of local communities may be developed. We also show an application study that simulates future growth in 22 communities of Geauga County Ohio. From this discussion, UGS demonstrates that various strategies for growth management can be tested and evaluated for their effectiveness. Furthermore, it is possible to use UGS to generate buildout scenarios to assist the assessment of environmental impacts caused by the simulated developments.

For information on the algorithms used by UGS to generate buildout scenarios, Lee et al. (1998) provides an overview of its procedures. Additional discussion on functions of UGS can be seen in Lee *et al.* (2002).

ACKNOWLEDGEMENT

We would like to acknowledge the funding and assistance from Geauga County Planning Commission via US Environmental Protection Agency Grant #: X97568901-0. We also wish to express our appreciation for the assistance and support by US EPA Westlake Office.

REFERENCES

Haith, D. A. and L. L. Shoemaker (1987) **Generalized Watershed and Water Conservation Practices for Pollution Control**. EPA-600/3-79-106. US EPA, Washington, D. C.

Lee, J., L. Erickson, T. Kulikowski and L. Tian (1998) "Managing urban sprawl with geographic information systems." **Environment and Planning B, Volume 25**: 865-879.

Lee, J., T. M. Brody, R. Zhang, H. Kim, and M. Bradac (2002) "Simulating urban growth on the web," **GeoSpatial Solutions**, 12(11): 42-45.

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Literature Review

Literature Review for Urban Growth modeling and Environmental Impact Analysis

Executive Summary

This report presents the results of literature review for the Phase One task of the proposed project: Development of a community-accessible urban sprawl impact assessment system in Northeast Ohio 15-county region for EMPACT project (US EPA Grant #985989-01-0)

The first part of the report discusses urbanization and urban growth as environmental issues. This is followed by reviews of various approaches currently available for environmental impact analyses.

The second part of the report reviews the urban growth models with recommendations made specifically for Northeast Ohio 15-county region based on local conditions and available databases.

A PDF format of this literature is available on the [download page](#).

Disclaimer: Study supported by the Environmental Monitoring for Public Access and Community Tracking (EMPACT) Program (Assistance ID X 985989-01-0). The views expressed in this paper are those of the authors and do not reflect the official policy or position of the EMPACT Program, the United States Environmental Protection Agency, or the U.S. Government.