Sustainable Urban Management: Balancing economic development and environmental protection goals

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Abstract:

The need to make land-use decisions on a national and regional scale in Canada was the impetus for the development of GIS. Roger Tomlinson, the acknowledged father of GIS, led the Agricultural Rehabilitation and Development team that developed what became known as the Canada Geographic Information System. Land use analysis has remained an important GIS application. This paper illustrates how criteria reflecting different planning goals can be incorporated into analysis by modifying the parameters of GIS tools in ArcGIS to enable planners and policy makers balance economic development and environmental protection goals.

Geographic Information Systems (GIS) is being deployed in many planning disciplines to combat urban and environmental problems in cities and communities around the world. GIS cutting-edge technology is an effective information management, analytical, and communication tool. Because of its effectiveness in saving time and effort, and its ability to easily share data and provide accurate results, GIS has been increasingly used in almost every field. This paper argues for basic changes in the way GIS software are commonly used as mapping tools. The widespread misuse and reliance on GIS-based applications as mapping tools should end. The ability to monitor economic, environmental, and social impacts on spatial dimensions provides a comprehensive lens for collaborative community decision making that goes beyond mapping and cartographic purposes.

GIS built-in capabilities allow for multiple criteria evaluation (MCE), which is mainly characterized by allocating various weights to assessment criteria for exploring and ranking different growth scenarios and alternatives. An important advantage of GIS spatial planning support tools is the convenience of changing the valuation criteria to visually illustrate and depict the implications of different spatial decisions and options. The availability of these capabilities needed for decision making in a single system makes GIS an effective planning support system and one that can be easily integrated into the planning processes and workflows.

This paper provides an example of how GIS spatial analytical tools are used as in shaping the decisions we make to foster urban growth management, namely identifying and selecting suitable sites for low-density residential development from two contradictory points of view. This paper will demonstrate the value of using GIS to accommodate future growth demand and guide the planning and annexation of cities. It will further provide a framework for sustainable growth management strategies that take into account both the socio-economic and environmental needs.

Keywords: **GIS, multiple criteria evaluation, land use, planning, geo-spatial, sustainability**

I. INTRODUCTION

Today, with the rapid global population growth and its socio-economic and environmental consequences, planners and policy makers are challenged on a whole new biblical scale both locally and globally. As policy makers we aspire to achieve desired future conditions. However, the world is rapidly changing creating new realties and new challenges for planning professionals. The combination of the natural world and human footprint resulted in many complex urban and environmental problems, such as social and environmental conflicts, resource limitation, air pollution, climate change, and increasing desertification, to name a few.

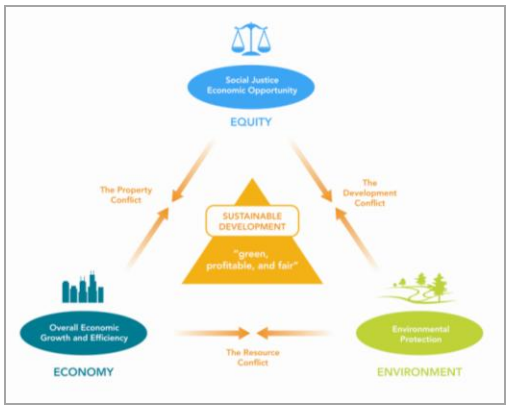

Fig. 1 The sustainability triangle of the three conflicting planning goals

Echoing the trends of other regions around the nation and the state of Illinois, the Champaign-Urbana region will continue to experience rapid population growth in the foreseeable future. In the wake of the proposed multi-modal transportation system, the area is expected to proliferate and attract more residents, suggesting that nearby areas need to be annexed to make room for new housing development including high- and low-density residential projects. To select appropriate areas for sustainable future annexation, city planners need to consider several important criteria for new housing construction, as illustrated in figure 1. These criteria reflect three main competing interests: equity, economy, and the environment, or what is known as the "3 Es" of sustainability. By and large, new development cannot be located in environmentally sensitive areas, such as watersheds, or in areas considered environmentally hazardous, such as near landfills. Predicting and managing future growth of the region is a compelling necessity that should be addressed today so that a more environmentally friendly and economically viable image of the future can be attained.

II. PURPOSE OF THE STUDY:

The focus of this study is to identify desirable locations for these expected new residential developments, namely low-density residential projects, based on two almost contradictory approaches. In essence, the sites will be analyzed and evaluated according to two scenarios. The first scenario is based on the developer's point of view, taking into account the purchasers' preferences. This scenario considers the developer's preferences pertaining to economic and marketing factors. To that end, the developer is interested in maximizing revenue and minimizing cost of the development paying little, or no, attention to environmental concerns. The second scenario is based on the environmentalists' point of view, which is quite the opposite of the first scenario. In this case, sites are ranked and evaluated to foster low impact and environmentally friendly development. Protecting the agricultural and prime forest lands and maintaining the integrity of the environment are the foremost decisive factors for the environmentalists' criteria. Site selection suitability analysis conducted in this study includes weighing the different factors in both scenarios and ranking desirable sites. The outcome of both scenarios will be evaluated and analyzed based on specific parameters discussed below.

III. TARGET AREA:

This study covers the Champaign-Urbana region, which is comprised of the municipal boundaries of both the city of Champaign and the city of Urbana in addition to a 1.5 mile buffer zone around the municipal boundaries of both cities, taking into consideration the established urban growth boundary, as shown in figure 2. According to the most recent census estimate, Champaign, the larger of the two cities, reached an estimated population of 79,389 in 2008, whereas Urbana has a population of approximately 38,725. The entire region has been growing slowly but steadily with Champaign experiencing rapid growth over the last three decades. The area has substantial potential for improvement and development opportunities with respect to businesses, employment, and in turn housing developments.

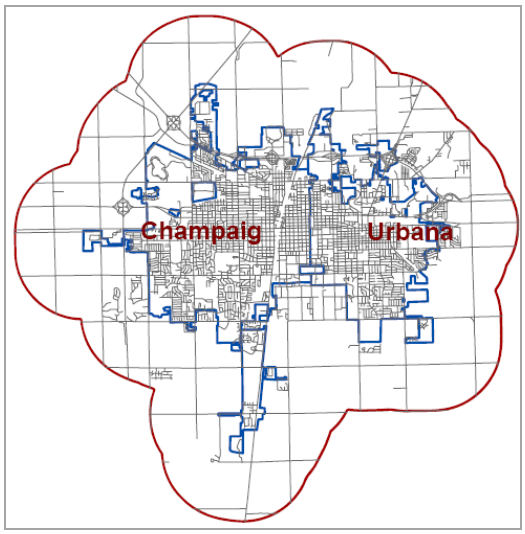

Fig. 2 boundary of the study area (Urbana-Champaign, IL)

IV. SITE SELECTION CRITERIA:

On the whole, two fundamental considerations materialize in determining the selection criteria, which are socio-economic and environmental factors. Low-density residential projects are high quality housing units characterized by a less compact pattern and advantageous location and site aesthetic features. More advantageous features mean a higher price. For the developer, ensuring high revenue and minimizing construction costs are of great importance. To that end, the first scenario attempts to rank suitable sites based on the developer's preferences. The second scenario represents a more environmentally contentious approach to growth management. This scenario provides a more discerning analysis regarding new developments by fostering environmentally friendly growth patterns and mitigating harm to the region's most precious environmental resources, meanwhile, avoiding locations that are more vulnerable to significant environmental hazards. In essence, the following criteria are used for the analysis:

A. Endogenous Factors (features of the location):

1. 100-year floodplain and wetland areas: the site must not be located in a floodplain designated area or areas that have high run-off rates to prevent and avoid any potential environmental hazards.
2. Soil type: the type of the soil must also be conducive for building housing unit. This means avoiding soil types with low bearing strength or poor drainage. Soil must be strong enough to establish foundations for multi-story buildings, namely two story dwelling units, and permeable enough to allow for the construction of septic systems.
3. Topography: relatively flat locations are preferable. Avoiding sites with steep slopes of more than 6% tends to reduce the cost of site grading which is necessary for adequate drainage and sewage systems.
4. Minimum lot size: the site should be of a minimum size to increase the overall project return on investment (ROI). Assuming 200 dwelling units per site, with a minimum lot size of 600 sq. ft. /DU, the minimum size of the entire site should be 120,000 sq. ft.

B. Exogenous Factors (features of the surrounding locations):

5. Proximity to existing urbanized areas: the site should be connected to the existing residential areas with high growth potential. This condition will ensure that the site is adequately served by the existing facilities and infrastructure, such as utilities, fire and police departments, medical facilities, educational facilities able to service with adequate capacity, and retail and commercial districts. It also ensures the availability of community's assets, such as parks and recreational facilities, in the vicinity of the site. Parks and other essential community facilities should be centrally located within and easily accessible from surrounding neighborhoods so that they can adequately serve a maximum range of a half-mile radius, which reflects the smart growth standard of a short five-minute walking distance. Therefore, a desirable distance from the nearest built-up areas should not exceed a half mile.
6. Environmental compliance: to preserve the environmental integrity and natural heritage of the area, the site should avoid prime agricultural land and open spaces.
7. Accessibility: the site must have access to transportation network. It should be well-connected by roads, railroads, interchanges, trials, and highways to ensure that the commute time required for work, entertainment, or shopping trips does not exceed 30 minutes. For simplification, a 300-meter buffer zone from major roads is considered an acceptable range for accessibility.
8. Proximity to industrial and landfill sites: a minimum distance of one mile from landfill and industrial locations, and other noxious land uses must be ensured in order to prevent

noise and eliminate immediate threat of harmful chemical emissions to public health. There are two major industrial sites located within the study area and another site located to the northeast of the region.

9. Airport location: there is only one major airport, the University of Illinois Willard airport, located to the south of the Champaign-Urbana region. A minimum distance of one mile is deemed sufficient to avoid adverse impacts of the airport noise.

V. GEOSPATIAL METHODS, ANALYSIS, AND RESULTS:

The analysis followed three major steps. These include data acquisition, data management and analysis. Data were collected from various sources such as the US Department of agriculture, USGS, Illinois State Geographical Survey, Illinois Department of Natural Resources, and the Inventory of Land based Disposal Sites to name a few. Data management included preparing the data for analysis, creating other derivative GIS layers and defining and delineating the data to fit within the boundary of the target area. Figure 3 shows the basic steps carried out to accomplish the analysis which is composed of two major categories: vector analysis and raster analysis.

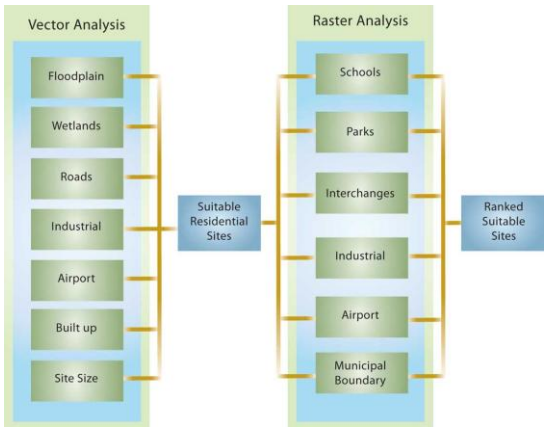

Fig. 3 analytical procedure

A. Vector-based analysis:

Vector-based analysis (using geo-processing tools) was performed on the first set of development criteria including floodplain, wetlands, road networks, industrial sites, airport location, built-up areas, and minimum site size. The final layers produced from the vector analysis are juxtaposed into one map shown in figure 4, which displays the first-cut of suitable sites for the low-density residential development. At this stage of the analysis, the output obtained does not reflect either the developer's or the environmentalist's concerns. Interestingly, most of these suitable sites are located outside the municipal boundaries of both cities, yet within the 1.5 mile boundary. This is due in part to the lack of sites of suitable substantial sizes available closer to the central parts of either city.

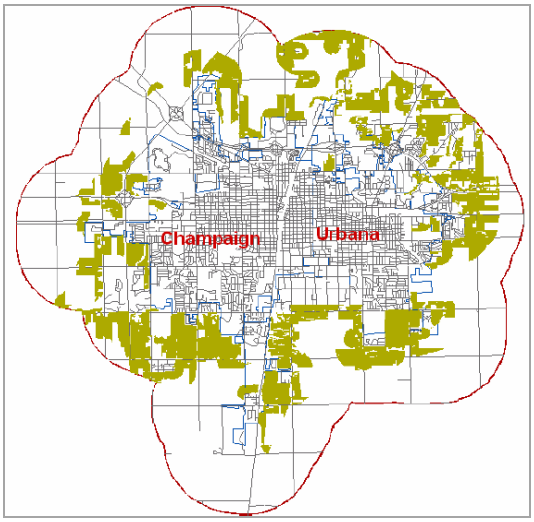

Fig. 4 vector analysis results

B. Raster-based analysis:

The raster-based analysis (using geospatial analysis, model builder, and density, proximity, and propensity tools) considers the two scenarios introduced in the beginning of the study (the developer's point of view and the environmentalists' point of view). Raster-based analytical steps and outcomes are illustrated in figure 5. All layers were classified according to a ten-category color scale for consistency purposes. In this analysis, the closer the location is to schools, interchanges, municipal boundary, and parks, the more desirable it is for development (designated compatible sites), while the closer the site to industrial locations and the airport, the less desirable it is for development (designated incompatible sites).

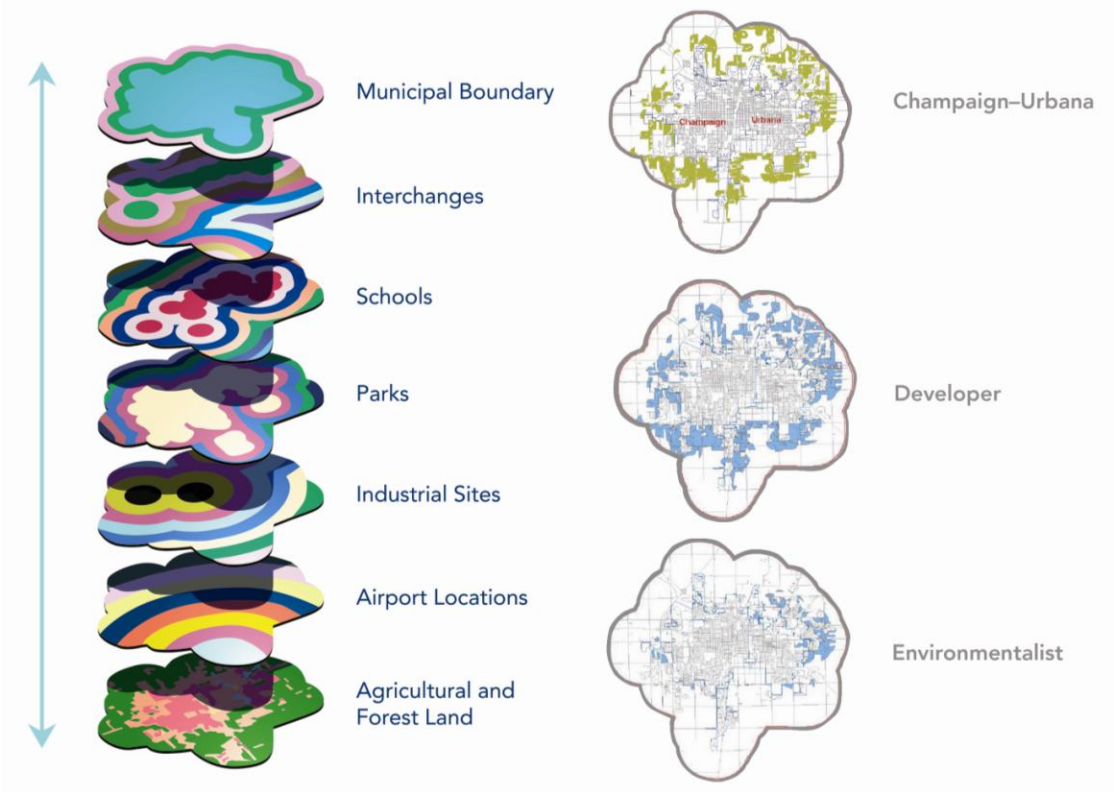

Fig. 5 layers and outcome of raster analysis

First scenario (the developer's point of view):

This scenario assumes that a private developer intends to initiate a new low-density residential subdivision in the Champaign-Urbana region. The developer knows that the key to achieving a successful and profitable project is to meet the preferences of the buyers. By doing so, the price of the housing units will be high and more revenue will be generated. To cater to the buyers' preferences and ensure project success, the best locations where facilities, amenities, and infrastructure are available must be identified as priority sites. To achieve these goals, different weights are assigned to each of the factors identified above based on these considerations. Proximity to schools, interchanges, and municipal boundary are assigned higher weights, while environmental factors regarding preserving the prime agricultural and forest land are given no or insignificant weight. After overlaying all the layers obtained from both analyses, a preference map that shows rated locations is obtained as shown in figure 6. The red color represents the most desirable locations from the developer's perspective. It is clear that the most desirable sites for development are located in west Champaign and northeast Urbana.

Second scenario (the environmentalist's point of view):

In this scenario, the environment is the main focus of the analysis and evaluation process. This approach aims to maintain the integrity of the agricultural and forest land of the region, which are assigned high weight values. By combining and weighting the different raster layers, a preference map that shows desirable locations is obtained for the entire area. The map shows that the most desirable sites, presented in red, are centrally located within the region avoiding the forest and agricultural land, which primarily exist on the periphery. Coinciding with the results obtained from the first scenario, the most desirable locations, according to this scenario, are those located in west Champaign and northeast Urbana. The difference is that this scenario is more conservative in allocating and land and recourses to accommodate future population growth and land use demand.

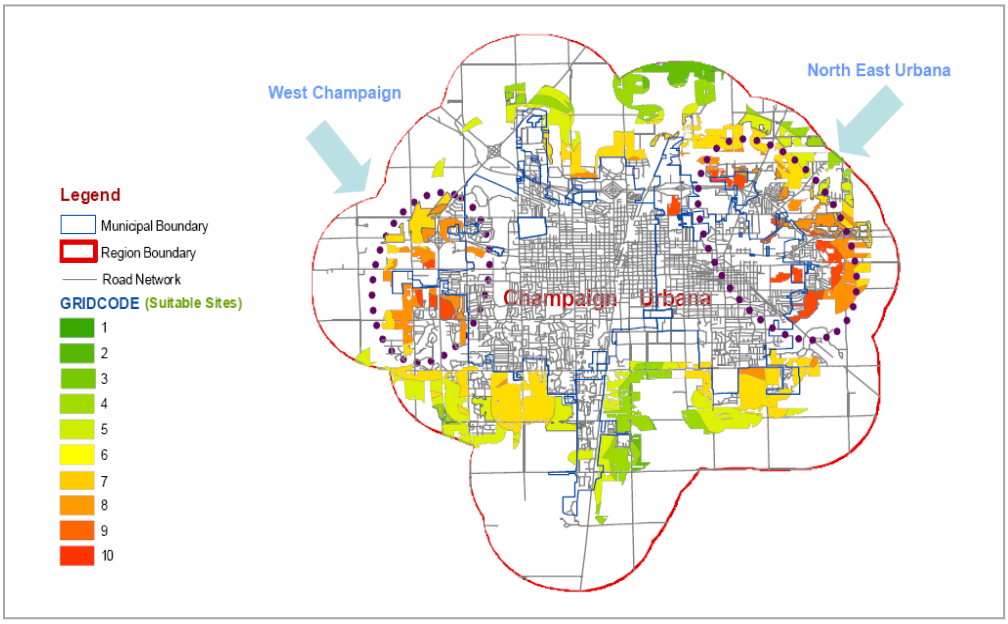

Fig 6 results from the first scenario (developer)

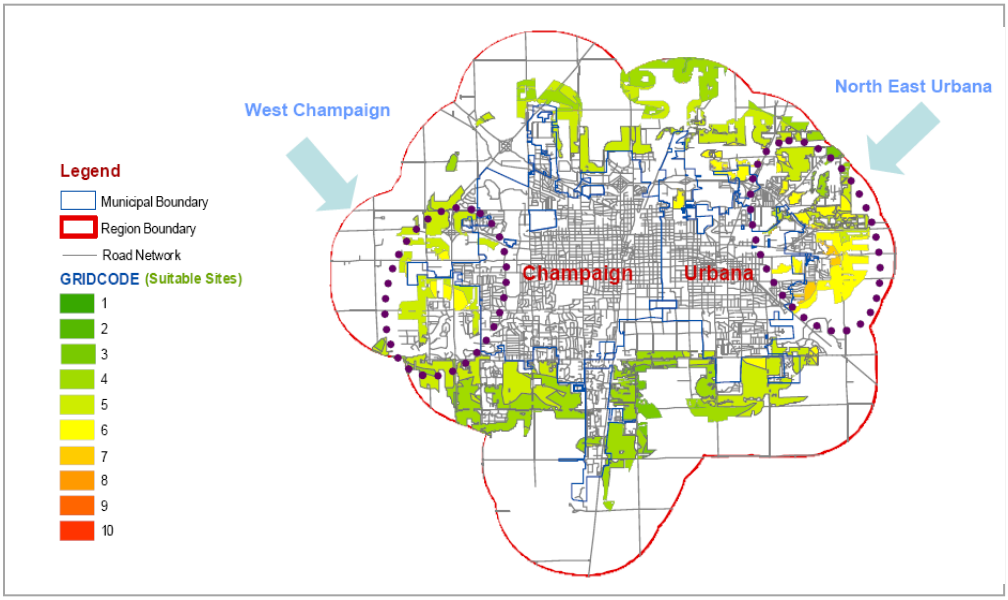

Fig. 7 results from second scenario (environmentalists)

VI. CONCLUDING REMARKS:

The findings from this study are summarized in figure 8, which provides a comparison of the results obtained from both scenarios showing locations with weight values higher than 5. It can be observed that the suitable areas for the low-density residential development in the first scenario cover a significantly larger portion of region than that of the second more conservative scenario. Because developers pay little attention to environmental factors, considerably large areas are proposed for development in the first scenario. In contrast, the fact that the second scenario relies on more conscientious efforts to preserve the natural resources of the region, greatly limits the amount of land perceived suitable for the proposed development. Knowing the potential sites for such development helps in determining future growth strategies including roads, infrastructure, schools, parks, shopping centers and other amenities. Knowing how and where cities tend to expand in the future helps in identifying locations and capacities of these amenities and assets needed for future expansion.

This study provided an example of how GIS is used to support planning tasks and help make better decisions regarding real-world planning issues and community development more effectively for the betterment of urban growth management practices. The previous example is used as a vehicle to shed light on the role of GIS in land use planning and decision-making. This study argues for the full utilization of GIS in order to maximize its contribution to the planning practice and refrain from limiting its applications to only mapmaking and cartographic purposes. Beyond mapmaking, GIS can deliver insight and actionable intelligence that helps planners accomplish their goals of livable and sustainable cities. The sole purpose of GIS based-technology is to provide state of the art analytical and management tools to study and explore spatial patterns and relationships in order make informed decisions regarding how to strike the right balance between socioeconomic development and environmental protection goals.

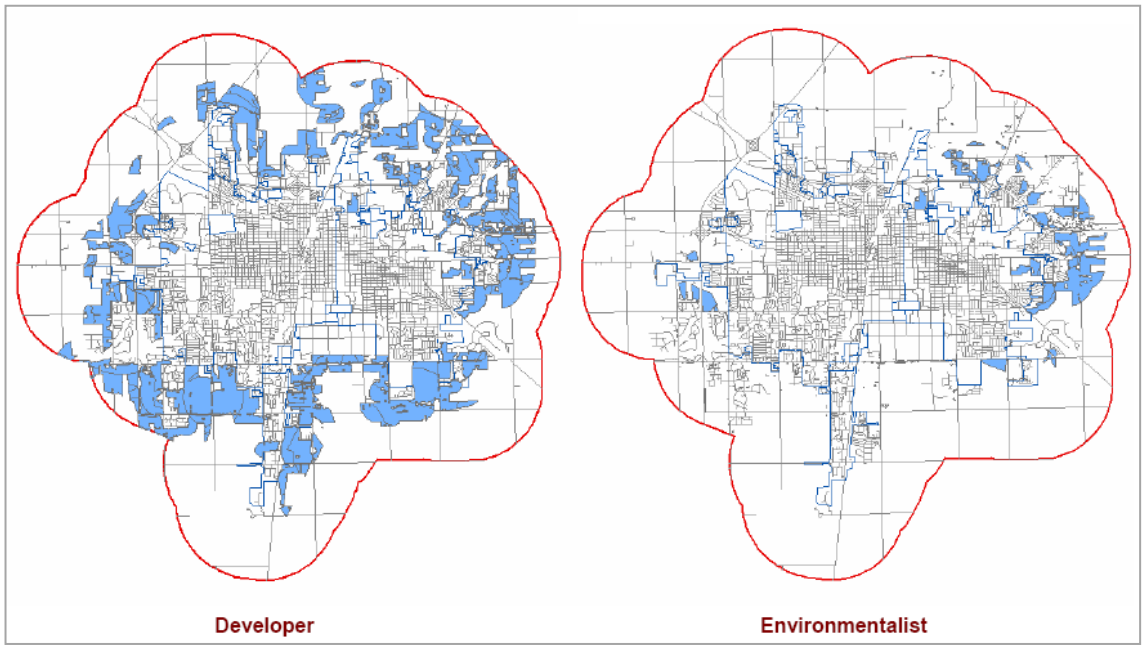

Fig. 8 suitable sites whose value is greater than 5

VII. ABOUT THE AUTHOR:

Dr. Ahmed Abukhater, GISP, leads ESRI's worldwide marketing strategies in planning and economic development. In his role as the Global Industry Manager for Community Development, Dr. Abukhater works to set the industry agenda through his vision of enterprise GIS, Planning 2.0, geodesign, smart growth planning, business attraction and economic gardening. As a noted planning expert, practitioner, educator, and scholar, he strives to promote a holistic approach to addressing community development needs in a multiscalar range of sectors.

As a planning practitioner, educator, and scholar, he strives to promote a holistic approach to addressing community development needs through the creation of effective planning and economic development solutions. His passion for data-driven analysis and decision making shaped his vision of geo-intelligence, promoting GIS as the industry standard technology and new wave of the future of planning around the globe. In this capacity, he is an advocate for full utilization of GIS in ways that maximize its contribution to the planning practice. Dr. Abukhater is dedicated to delivering global access to knowledge of GIS solutions in planning and economic development applications through his thought leadership and cutting-edge international planning initiative.

Dr. Abukhater holds a Ph.D. in Community and Regional Planning from the University of Texas at Austin with a focus on water resources management and conflict resolution and mediation, a Master's degree in Urban and Regional Planning from the University of Illinois at Urbana-Champaign and a Bachelor's degree in Architectural Engineering. Throughout his career, Dr. Abukhater has authored numerous publications, served on many governing and advisory boards, and received over 20 prestigious awards for his work. He is married and a proud father of three children.