Urban sprawl: The GIS and remote sensing data assessments

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ABSTRACT. *A central issue around which the recent growth literature has evolved is that of urban sprawl. The process of urbanization is a universal phenomenon taking place the world over, where human settle. Expansions of interest in the modeling and analyzing of this process and the problems to which they are applied should be taken in account. Urban planners require information related to the rate of growth, pattern and extent of sprawl to provide basic amenities. Patterns and extent of sprawl could be modeled with the help of such information.*

This paper brings out the extent of sprawl using Geographic Information System (GIS) and Remote Sensing imagery. These techniques based study is carried out to comprehend the process of sprawl. In one hand, geographic positioning, topology and surface measurements are basic GIS properties which enable highly precise locational referencing of spatial phenomena. The growing uses of Remote Sensed imagery are contributing to unprecedented surveillance of the environment and to monitor and measure urban sprawl in other hand. For this purpose, this paper tries to give some possible reflections that help us to develop the analytical tool that may help us to improving the way towards the amplification of the analysis paradigm.

This article focuses on the issues widely and frequently used in the examination of the urban spread out, which are scattered in the literature. It begins by laying out the urban sprawl debate. We will offer an overview and discussion of the contemporary issues related to this phenomenon. Then, the paper follows the GIS assessment conducted along some different ways that consist of the most influential advantages. Finally, we will expose the technique of Remote Sensing imagery which provides several information bases for analysis of the sprawl feature.

KEYWORDS: *Urban Sprawl, Geographic Information System (GIS), Remote Sensing, Modeling.*

1. Introduction

Urban Sprawl is a major problem in the course of the urban development in some countries in this beginning of 21st century. Most of the urban sprawl is considered to be the expansion of low density accompanied by a series of environmental and socio-economic issues. Across states and cities there is a growing awareness of, and concern about urban sprawl.

In addition, land development has been out of control and the construction land has kept expanding blindly, especially in the marginal areas of some metropolises.

So, urbanisation has evinced interest from a wide section of the society including experts, amateurs, and novices. It has been one of the burgeoning issues of study in the present development situation where increasing population have paved way for rapid expansion of the urban centers. GIS and remote sensing based study is carried out to comprehend the process of sprawl.

2. The urban sprawl debate

Sprawl is a term that is often used to describe perceived inefficiencies of development, including disproportionate growth of urban areas and excessive leapfrog development. Sprawl is acumulative result of many individual decisions and it requires not only an understanding of the factors that motivate an individual landowner to convert land, but also an understanding of how these factors and individual land-use decisions aggregate over space. Some of the causes of the sprawl include - population growth, economy and proximity to resources and basic amenities.

Many studies indicate that urban sprawl is the pattern, density, and rate of new urban growth that create the appearance of sprawl. Population dynamics are often cited as a driving force behind urban sprawl.

Population increases and the consequences of unplanned urbanization are directly related to recent rowth management practices that seek to influence the way in which built-up land can proliferate. The pattern, density, and rate at which built-up land develops are the basis for one contemporary debate: urban sprawl versus urban growth. As a contemporary planning issue, the debate over sprawl is framed by different disciplines and their understanding of how and why urban areas grow. Although urban sprawl is a type of urban growth, sprawl is dependent on the way in which development occurs.

2.1. Issues related to urban sprawl

Allen et al (2003) said that Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution.

As population increases, so does the need for new housing, schools, and transportation networks. In the urban world today, industrial, commercial, and residential districts are markedly different from years past. Decentralization is a trend indicative of urban sprawl and present day industrial, commercial, and residential areas are no longer necessarily a part of the urban core.[1]

Rather, these types of development are often found in low-density areas that are separated from the major urban area by large tracts of homogeneous land. Hence, the needs for larger transportation networks and in turn a greater dependency on automobiles, which produce more air pollution. As new roads are put in place, precious farmland is often left unprotected from commercial or residential developers (Hathout 2002). The greater the imperviousness of an area the more water runoff one can expect, which is the catapult for water pollution (Wilson et al 2003). Without regulations on urban growth, consequences of urban sprawl are likely to continue.

2.2. The distinction between growth and sprawl

As urban growth occurs, that growth is often confused with urban sprawl. However, there is a distinction between urban growth and urban sprawl. Cities often experience growth either physically, by population, or by a combination of both. Urban sprawl is much more complicated because it may or may not qualify as urban growth. How a city grows can create the appearance of sprawl. Such urban growth may appear as a low-density leapfrog pattern, a linear or strip development pattern along highways, or a tightly condensed pattern of new development around pre-existing built-up landscapes (Nechyba et al 2004). Without urban growth there would be no appearance of urban sprawl.

2.3. Definition of urban sprawl

The debate over urban sprawl is relatively new, yet there are many definitions of urban sprawl. This is due in large part because there is no consensus on what sprawl is and what is simply urban growth. Despite vivid examples of what some may classify as sprawl over a given landscape, there is no clear definition of urban sprawl that is shared by all who study urban phenomena. There are definitions based on characteristics of urban sprawl, effects of urban sprawl, and factors leading to urban sprawl.

[1] For more details see Nechyba et al (2004).

Further, definitions of urban sprawl are also influenced by the people that create them. Many definitions of urban sprawl may include bias towards being pro or con urban development.[2]

Ottensmann (1977) defines urban sprawl as "the scattering of new developments on isolated tracts, separated from other areas by vacant land."[3]

Ewing (1997) characterizes urban sprawl as "leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments."[4]

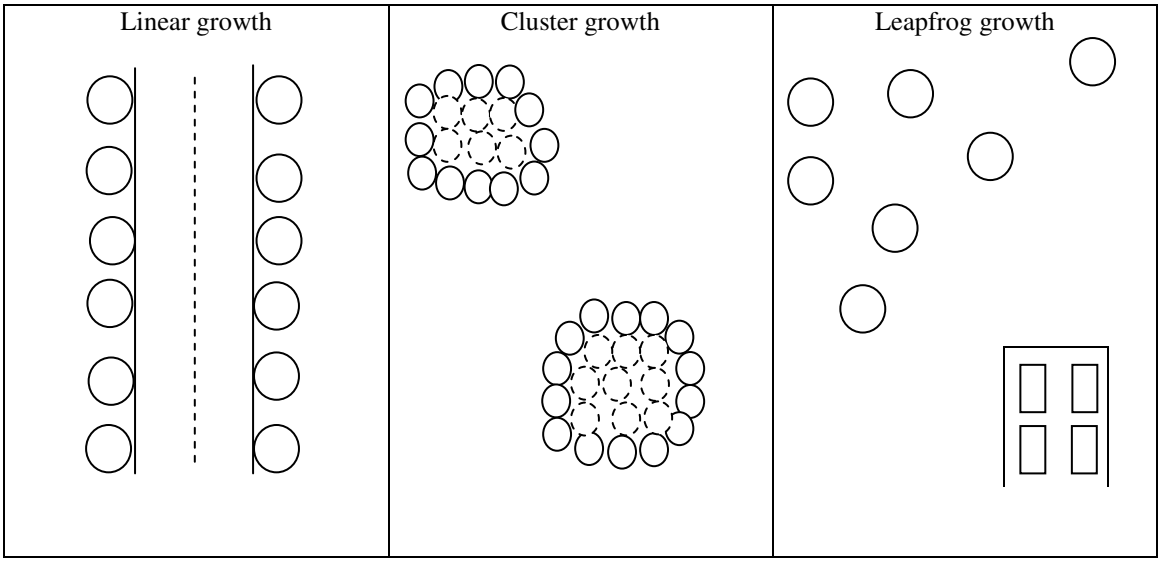
Zhang (2001) states that "urban sprawl results from poorly planned, large scale new residential, commercial and industrial developments in areas previously not used for urban purposes."[5]

Urban sprawl is often difficult to gauge because it can occur slowly over time. Wilson et al (2003) argue that without a universal definition of sprawl it is extremely difficult to model.

2.4. Types of urban sprawl

Sprawl is urbanization that takes place in either a radial direction around a well-established city or linearly along the highways over a given period of time (Sudhira et al 2004). Clearly, radial and linear are just two types of map patterns that sprawl can take. Sudhira et al. (2004) state that to understand the complexity of urban sprawl, land use change analyses and urban growth pattern recognition must be determined. Throughout the literature, there is ambiguity on the difference between urban growth and urban sprawl except to suggest that urban sprawl is a type of urban growth.

Figure 1. *Types of urban growth*



Source: Berckley A. , A GIS assessment in Richmond, Virginia, Thesis of science in geography, the Faculty of Virginia Polytechnic Institute, p. 13.

2.4.1. Linear growth

[2] It is important to note a few of the definitions from different time periods.
[3] Ottensmann, J.R., *« Urban Sprawl, Land Values and the Density of Development »*, Land Economics, 53 (4): 389-400, 1977, p. 389.
[4] Ewing, R., *« Counterpoint: is Los Angeles-style sprawl desirable »*, Journal of the American Planning Association 63 (1):107-126, 1997, p. 108.
[5] Zhang, T. 2001. « *Community features and urban sprawl: the case of the Chicago metropolitan region »*, Land Use Policy 18: 221-232, 2001, p. 221.

The linear pattern of sprawl is classified as high and medium density built-up areas of development located along the highways. (Sudhira, 2004) These major highways include I-90, I-390, I-490, I-590 and some state Highways.

2.4.2. Cluster expansion

Cluster or expansion growth takes place when extensive commercial development occurs in a linear pattern along both sides of major arterial roadways. To detect cluster growth, linear growth factors need to be excluded. In order to exclude the linear growth factors, growth data along the traffic routes is needed to be picked out. However, here's a problem in choosing buffer distance. If the distance is too small, the influence from main traffic routes could not be completely eliminated. If it is too big, the necessary growth data might be excluded as well. In this case, this project uses 1miles buffer distance for the main traffic routes (the same as linear growth pattern) and 50m for the others.[6]

2.4.3. Leapfrog

Leapfrog development occurs when developers build new residences some distance from an existing urban area, bypassing vacant parcels located closer to the city. Medium density areas with low connectivity indicated leapfrog patterns.[7]

2.5. Visualizing urban sprawl

Before the introduction of Geographic Information Systems, mapping any phenomenon took an extremely long time. Maps produced through manual cartography for comparison were planned well in advance of a due date. Computer aided maps without GIS were very rudimentary and were not very aesthetically pleasing to say the least. The availability of different types of spatial data allows a GIS user to map virtually any phenomena with a geographic dimension applied to it. In addition, large amounts of data are processed before the creation of a map with much less work than with manual cartographic techniques. With a GIS, maps can be compared in a fraction of the time and can be done at variable scales with ease.

2.6. The justification for studying urban sprawl

Sudhira et al. (2004) state that understanding the patterns of urban sprawl can help with natural resource planning, natural resource utilization, and the provision of infrastructure facilities. Urban sprawl creates inefficient use of land, land resources, and large-scale encroachment on agricultural land[8]. The most pressing problem is the substantial loss of fertile agricultural land in many coastal cities because of short term economic considerations.[9]

Sprawl has become the metaphor of choice for the shortcomings of the suburbs and the frustrations of central cities.[10]

2. Urban sprawl and the GIS assessments

GIS reveals spatial patterns of urban sprawl by measuring distances of new urban growth areas from town centers and roads for example (Gar-On Yeh et al 2001). Because urban development is irreversible,

[6] Adopted from Fang L., *Land use change and city sprawl assessment: a case study in Rochester City*, course GEO 575, p. 7
[7] Ibid.
[8] Gar-On Yeh et al (2001).
[9] Ibid.
[10] Galster, G., Hanson, R., Ratcliffe, R.M., Wolman, H., Coleman, S., Freihage, J., *« Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept »*, Housing Policy Debate 12 (4), 2001, 681-715, p. 681.

GIS simulates future land development (Lee et al 1998). A Geographic Information System is a decision support system that can facilitate urban planning.

A map provides the visual aspect from which studies on urban sprawl can begin in relation to urban growth. A Geographic Information System is useful for mapping the spatial distribution of urban areas. Unlike traditional cartographic methods, GIS allows for the manipulation of different types of data in one map frame. Mapping urban phenomena is a crucial part of quantifying urban sprawl. While many layers of data are used to create a map of urban growth, ultimately it is the map that tells the story about the level of urban sprawl over a given landscape. This type of mapping involves a temporal signature in which two or more time periods are used for comparing amounts of urbanization. One base map shows urban or built-up land in a starting year and another map shows the developed land from the end year. Therefore, mapping the extent of urbanization over a given period of time is an essential part of understanding urban sprawl.

2.1. Geographical information and geographic information systems

The geographical information is a representation of an object in which a real phenomenon located in space at a given time. Geographic information is characterized by a purely spatial component and a semantic component.[11]

At the first light of the third millennium, the digitization of spatial objects or phenomena proved effective and efficient in the better management of local development issues. Tools and instruments are invented and help to manage the space and phenomena behind it. Among these tools, we note the Geographic Information Systems. GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The acronym GIS is sometimes used for geographical information science or geospatial information studies to refer to the academic discipline or career of working with geographic information systems.[12]

2.2. GIS and local development

If we consider the definition of local economic development to be the improvement of land and infrastructure for the benefit of the community as a whole, it is clear that GIS have a key role to play. GIS are now used extensively in government, business, and research for a wide range of applications including environmental resource analysis, land use planning, locational analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis.

2.3. GIS and spatial planning

GIS can better understand all the information on one-way and becomes a guide for the best choice of urban traffic. It also allows to update the dynamic that know the ways in urban areas as new development will be done automatically updated in the information system, more specifically, it leads to:

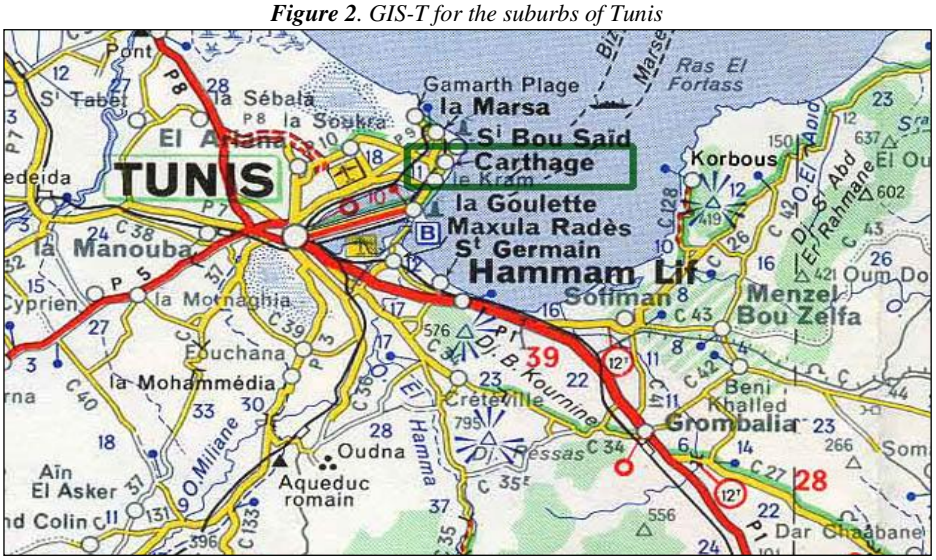
- ✓ Mapping networks (urban transport, water, sanitation, electricity, etc.),
- ✓ Monitoring urban expansion, create zoning regulations to provide for the possible extension of the city, with services that must accompany it;
- ✓ Monitor extension possible nuisances (noise, pollution).

Although traffic safety is a concern to many urban residents, the role of urban design on crash incidence is typically not considered as part of the transportation planning and design process. To better account for the effects of urban design on crash incidence, the authors recently sought to develop a GIS. This technique will assist planners and urban designers in systematically evaluating the effects of community design on traffic safety. GIS have become increasingly important in the transport sector since

[11] Degréne and Salgé, 1997.
[12] ESRI, *Geographic Information Systems as an Integrating Technology: Context, Concepts, and Definitions*, Retrieved 9 June 2011.

the 1990s, so much so that a new acronym has been created: the GIS-T (Thill, 2000; Dueker et al., 2000a).

***Figure 2**. GIS-T for the suburbs of Tunis*



2.4. GIS and urban dynamics

GIS is a readily available spatial analysis tool which gives unique and unparalleled insights into the natural and manmade environments due to its strength to link the "generic information" with its "location". GIS is a powerful tool which not only analyses the present environmental scenario but also helps in projecting the future, in other words, one can effectively use the GIS tool for past, present and future studies on environment and its protection for the generations to come in future.

The few examples where GIS can be effectively used are in Environmental planning, Ground water contamination, Fresh water and saltwater interface, Water quality, Solid waste and Waste water management, Air & Water pollution, Natural Hazards and their mitigation etc.

GIS can:

- ✓ Monitor land use;
- ✓ Cross the information collected with statements operators (political, agricultural and common);
- ✓ Diagnose the specific needs of certain operations and practice a less polluting agriculture (precision farming).

3. The technique of Remote sensing imagery

3.1. Process of urban sprawl: application of remote sensing data

One of the prerequisite for understanding urban sprawl is successful land use change detection. This is made possible by accurate registration of the satellite imageries so that the overhead pixels represent the same location. There is a wide range of techniques used for land use change detection to study urban sprawl. Some of the major techniques include composite image, image comparison, comparison of classified images, combination of classified images, and radar classification and so on. One of these techniques is based on the comparison of the classified images.

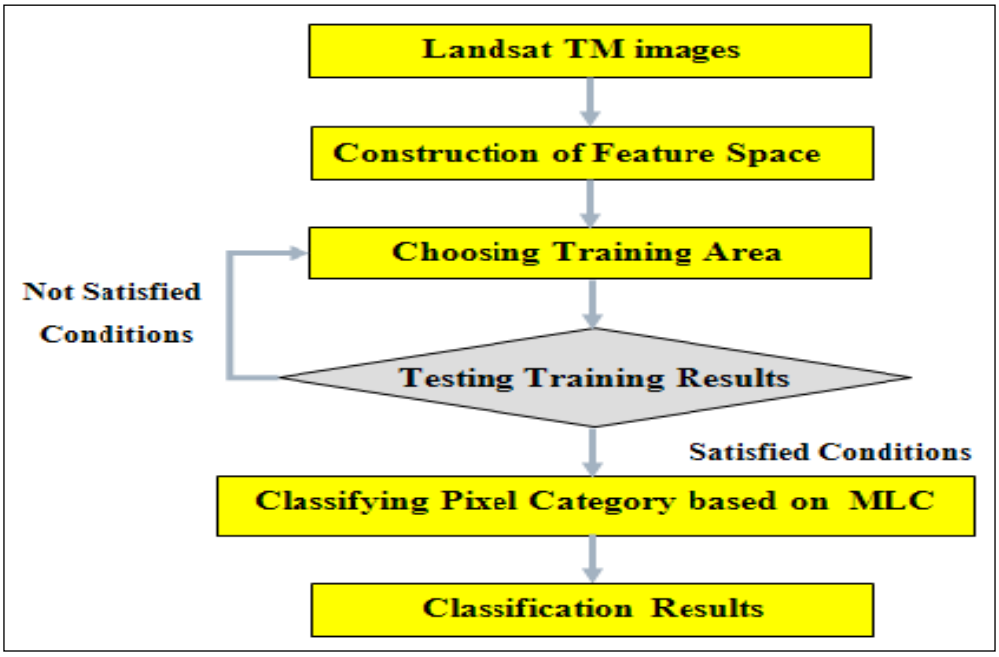
Remote Sensing is the science of making inferences about objects from measurements, made at a distance, without coming into physical contact with the objects under study.

Remote sensing means sensing of the earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment.'

3.2. Remote sensing image classification

The technique of remote sensing provide a powerful tool for studying urban issues, like land use/cover change, urban growth modelling, urban sprawl etc. Remote sensing image classification is one of important application aspects for remote sensing technique, through computer processing with specific software like ERDAS13, the results of the classification of land uses can be auto-outputted. In this research, I used the multi-temporal Landsat TM images which covered whole Nanjing city to carry out the image classification. The traditional information extraction from remote sensing image is mainly based on spectral respond feature, so the classification accuracy was not high because of the mixed pixels.

Figure 3. *The process of image classification*



Source: Feng L., *« Applying remote sensing and Gis on monotoring and measuring urban sprawl: a case study of China»,* Revista Internacional Sostenibilidad, Tecnología y Humanismo, N°4, 2009, p 50.

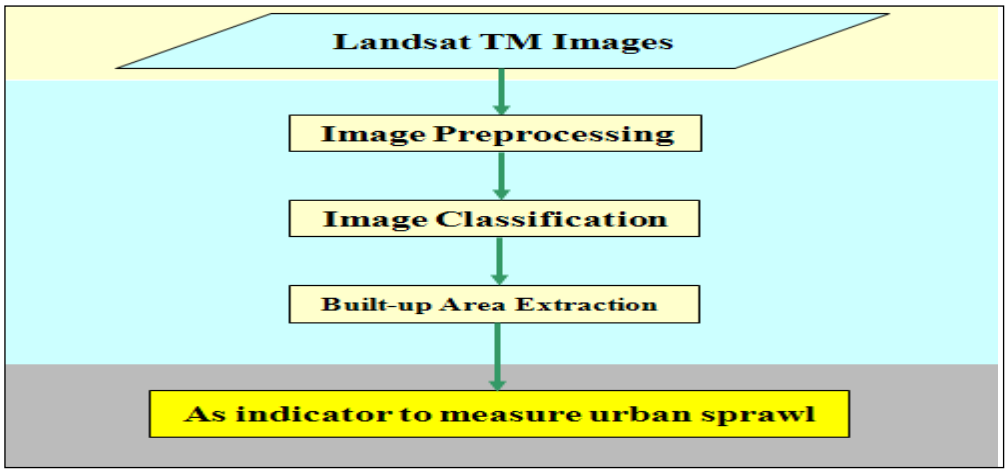
The method of Maximum Likelihood Classification was used to classify the different land uses, and then built-up areas were recognized and extracted from the classified images

3.3. Buil-up area extraction

Training areas are small samples of homogeneous areas selected by the image analyst prior to classification. Appropriate training areas are determined from maps, ground data, interpreted stereo airphoto or other information.

[13] The latest version is 2011, version 11.0.4. ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in GIS or in computer-aided design (CADD) software.

Figure 4. *The technique sketch of built-up area extraction*



Source: Feng L., « Applying remote sensing and Gis on monotoring and measuring urban sprawl: a case study of China», Revista Internacional Sostenibilidad, Tecnología y Humanismo, N°4, 2009, p 51.

4. New prospects

4.1. Combat against urban sprawl

Land use patterns across countries show that tensions are arising almost everywhere between our need for resources and space and the capacity of the land to support and absorb this need. Urban development is the main driver. Anticipated growth of the urban population in the coming decade, will further fuel these trends. Globalisation, transport networks, socio-demographic changes, societal aspirations for the 'urban culture' and uncoordinated land-planning mechanisms at various levels are the main sources of the environmental unsustainability of our cities. Scientists, planners and policy-makers are becoming increasingly aware that adequate decisions on urban development cannot be made solely at the local level.

Otherwise, here are some recommendations for decision makers to relieve the bad effects caused by urban sprawl:

_ Conserve and restore the natural environment, cultural and historical resources, and traditional rural lands;

_ Protect and ensure the integrity of environmental assets critical to public health and safety;

_ Promote integrated planning across all levels of government to address issues on a statewide, regional and local basis.

The history of human culture suggests that 'landscape' is one of the earliest and most obvious concepts for perceiving and describing our changing environment, be it artificial or not. It is at the landscape level that changes of land use, naturalness, culture and character become meaningful and recognisable for human interpretation. In that sense, landscape is as much vision as it is reality. A landscape is essentially a photograph of what is going on; it reveals, in short, who we are. With urban sprawl-generated landscapes in continuous flux, we indeed reveal a lot about the footprints we will be leaving for the next generations.[14]

4.2. Response to new technologies

In the next few years, GIS and Remote Sensing imagery are likely to be the beneficiaries of a large number of technical developments. Many of these are already apparent, while others have yet to emerge.

[14] Adopted from EEA Report, *Urban sprawl in Europe : The ingnored challenge*, n°10, 2006. p. 45.

Wireless communication may radically change practices in field data collection, and continuing miniaturization of hardware will likely impact our ability to compute in field settings.[15]

4.3. Application to other fields

Finally, and in a sense reversing the previous section, there is much to be gained by looking for applications of GIS and Remote Sensing imagery developments in other fields. The problems of representation of moving objects are not unique to urban sprawl, but are motivated by similar issues in wildlife management, health, and many other areas. GIS and Remote Sensing are a generic technology, designed to provide useful functions across a range of application areas. Similarly, GIS and Remote Sensing are most productive when their developments and principles are generic, motivated perhaps by a single field but with implications for many other fields. The final challenge is to find fields that are substantively analogous to urban sprawl application, and to make research advances by taking advantage of a broadly conceived approach that sees the parallels between widely disparate applications.[16]

Uses of GIS and Remote Sensing imagery range from indigenous people, communities, research institutions, environmental scientists, health organizations, land use planners, businesses, and government agencies at all levels.

Uses range from information storage; spatial pattern identification; visual presentation of spatial relationships; remote sensing - all sometimes made available through internet web interfaces, involving large numbers of users, data collectors, specialists and/or community participants.

Some examples include: GIS Application in crime, history, hydrology, indigenous, public, transportation engineering. Other applications include the use of GIS techniques for water, wastewater and stormwater systems, and in solid waste management.

The combined use of remotely-sensed images and vector GIS data has received considerable interest in recent years. The benefits of integration to users of both GIS and remote sensing for various applications are reviewed and some thoughts are given on terminology and future directions in this field[17].

5. Conclusion

The representation of geographic phenomena in digital databases is one of the most central and fundamental issues in Geographic Information System. This paper uses Geographic Information Systems (GIS) mapping and Remote Sensing data to measure sprawl.

It is important to note a few of the definitions from different time periods. Here the paper was presented those definitions in a chronological manner in order to show a progression in the concept of urban sprawl. The advancement of GIS data models to allow the effective utilization of very large heterogeneous geographic databases requires a new approach that incorporates models of human cognition.

The use of Geographic Information Systems modeling has become quite prevalent within the field of urban sprawl research. This paper has attempted to define GIS and its features and identify how GIS plays a key role in delivering the information needed to support the urban sprawl program. Illustrative examples of GIS were presented to show how the use of GIS technology facilitates the process of presenting spatial planning and urban dynamics. GIS is becoming more suitable for emergency operations and is integrating tools that allow real-time display of information. The GIS allows, in many respects, the enhancement of technical capacity and decision making in the territorial management.

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[15] Adopted from Goodchild M. F., *« GIS and transportation : Status and challenges »*, Geoinformatics 4 :2, pp : 127-139, 2000, p. 136.

[16] Ibid, p. 137.

[17] Hinton J.C., *« GIS and remote sensing integration for environmental applications »*, International Journal of Geographical Information Systems, Vol. 10, Issue 7, 1996, pp: 877-890.

6. References

Allen J., Lu K., « *Modeling and Prediction of Future Urban Growth in the Charleston Region of South Carolina: a GIS-based Integrated Approach* », Conservation Ecology 8 (2): 2, 2003.

Denegre, J. et Salge, F., *Les systèmes d'information géographique*, 2nd Ed. Paris : Presses Universitaires de France, 2004.

Duecker, K. and Ton, T., *Geographic information systems for transport*, In Hnadbook of transport moselling (dir: Hensher D., Button K.), Elsevier Science, Oxford, 2000a, pp.253-268.

EEA Report, *Urban sprawl in Europe : The ingnored challenge*, n°10, 2006.

ESRI, *Geographic Information Systems as an Integrating Technology: Context, Concepts, and Definitions*, Retrieved 2011.

Ewing, R., 1997, *« Counterpoint: is Los Angeles-style sprawl desirable? »,* Journal of the American Planning Association 63 (1):107-126.

Fang L., *Land use change and city sprawl assessment: a case study in Rochester City*, course GEO 575.

Feng L., *« Applying remote sensing and Gis on monotoring and measuring urban sprawl: a case study of China »*, Revista Internacional Sostenibilidad, Tecnología y Humanismo, N°4, 2009.

Galster, G., Hanson, R., Ratcliffe, R.M., Wolman, H., Coleman, S., Freihage, J., Wrestling Sprawl to the Ground: *« Defining and Measuring an Elusive Concept »*, Housing Policy Debate 12 (4), 2001, 681-715.

Gar-On Yeh, A., Xia, L. 2001, *« Measurement and Monitoring of Urban Sprawl in a Rapidly Growing Region Using Entropy »*, Photogrammetric Engineering & Remote Sensing 67 (1):83-90.

Goodchild M. F., *« GIS and transportation : Status and challenges »*, Geoinformatics 4 :2, pp : 127-139, 2000.

Hathout, S. 2002. *« The use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada»*, Journal of Environmental Management 66: 229-238.

Hinton J.C., *« GIS and remote sensing integration for environmental applications »*, International Journal of Geographical Information Systems, Vol. 10, Issue 7, 1996, pp: 877-890.

Lee, J., Tian, L., Erickson, L.J., Kulikowski, T.D 1998, *« Analyzing growth-management policies with geographical information systems »*, Environment and Planning B: Planning and Design, 25 (6): 865-879.

Manishika J., Mohan Lal S., *GIS and Remote Sensing Applications to study urban sprawl of Udaipur*, India , The 17th International Research Symposium on Computer-based Cartography Shepherdstown, West Virginia, USA, September 8-11, 2008.

Nechyba, T.J., Walsh, R.P., 2004. *« Urban Sprawl»*, Journal of Economic Perspectives 18 (4): 177-200.

Ottensmann, J.R., 1977, *« Urban Sprawl, Land Values and the Density of Development »*, Land Economics, 53 (4): 389-400.

Sudhira, H.S., Ramachandra, T.V., Jagadish, K.S 2004, *« Urban Sprawl: metrics, dynamics, and modeling using GIS»*, International Journal of Applied Earth Observation and Geoinformation 5: 29-39.7

Thill, J. C., 2000, « *Geographic information systems for transportation in perspective »,* Transportation Research part C, n°8, 2000, pp. 3-12.

Wilson, E.H., Hurd, J.D., Civco, D.L., Prisloe, M.P., Arnold, C. 2003. *« Development of a geospatial model to quantify describe and map urban growth »,* Remote Sensing of Environment 86: 275-285.

Zhang, T. 2001, *« Communi ty features and urban sprawl: the case of the Chicago metropolitan region »*, Land Use Policy 18: 221-232.