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Urban form study: the sprawling city—review of methods of studying urban sprawl

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Abstract There is a large body of research on urban forms. This review paper focuses on the urban sprawl using new and old approaches and new techniques from the subfield of urban Geography. There has been a debate among researchers about the definition of the sprawl, which makes it difficult to suggest a reliable model of the urban sprawl. This review is extremely selective. Numerous papers have focused on measuring the in terms of its physical cost or the environmental and transportation measures linked to this phenomenon. Several attempts have been made to improve the measurement of the sprawl using new approaches. Furthermore, this paper show that certain researchers did not attempt to explore new methods to investigate the urban sprawl in the past and present overlay layers for many years, researchers may use cartography techniques, for example, thereby collecting 20 years of data to match layers and show the differences in any metropolitan area. Several problems remain like differences in the understanding of the sprawl among planners and between other researchers interested in this issue. Also, it is problematic to find one measure, such as mixing different measures together to distinguish between car density and resident density. This study evaluated and reviewed old and recent studies to show that the most important issue in the urban sprawl relates to measurements. Incorporates inform and which measure is best. This article argues that urban spatial expansion reviews some of articles written on urban sprawl and showing the different approaches to studying.

Keywords Urban sprawl · GIS · Approaches · Urban form · Density

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Introduction

Many works have been published about the sprawling city as a type of urban form. In my judgment, This is a very positive phenomenon, as advocated by many studies. A significant problem in all those studies can be summarised in the following questions: what is the concept of sprawl? Why do some people measure this concept in different ways? Most papers reviewed mention that the urban sprawl first existed with the appearance of the first cities (Franz et al. 2007). When the inner-city areas become crowded, there is a tendency for cities to expand their boundaries into neighbouring rural lands. Several articles point out that one of the earliest documented examples of this was Rome, in the very beginning of the Christian era.

There was an intense debate about the first use of the sprawl concept in the last century. For example, Buregmann stated that in America it was first used in the early 1900s while others mentioned that it started

between 1970 and 1990 (Bruegmann 2005). Moreover, the term "sprawl" was first used in 1937 by Drapar of the Tennessee Valley Authority in during a national conference of planners (Ngoran 2014). Many papers on the sprawl mentioned that in the United States, in 1960, the American population lived in almost exactly equal proportions in central suburban areas. By 1975, the suburban component had risen to 3%, but the central city portion had fallen to 29.6%. In the United Kingdom, however, this phenomenon was first discussed in 1935 when urban planner, Howard, introduced a new idea called the *green belt* to prevent to urban sprawl and keep land permanently open. In terms of more ancient history, ideas were suggested to prevent the sprawl, such as when Prophet Mohammed in the seventh century established a green belt around the city of Medina in Arabia, by prohibiting any further removal of trees within a twelve-mile radius around the city (Iqbal 2005). Also, The Old Testament outlines a proposal for a green belt around the Levite towns in the Land of Israel (Small 2009). Moses Maimonides also mentioned that the green belt plan from the Old Testament referred to all towns in Ancient Israel (Small 2009).

Many urban authors in urban planning, in past and present articles, used numbers to support their ideas. Even though there is not one agreed definition of the urban sprawl, in some articles it is described as a physical pattern relating to a low-density expansion of large urban areas, under market condition, mainly into the surrounding agricultural areas (Satterthwaite et al. 2010). Also, it has been defined as the expansion of automobile, low density development and drivers due to demographic factors, population growth, economic factors, price of land or inner city problems such as poor air quality, noise, small accommodations, transportation problems, car ownership, the low cost of fuel, housing preference and the need for more space per person.

Historically, the urban sprawl has been the result of many main factors such as the increasing population and the improvement of mobility through better transportation links made possible by new technology. For example, in Europe the growth of built-up areas was in its peak in 1950–1960, when the average annual growth rate reached 3.3%. Geographers and urban planners in the east Europe hold different views about the sprawl or, in other words, the causes of the sprawl are different in the West and East. For example, culture and religion may be two significant reasons for the non-occurrence of the urban sprawl. Also, political issues may also have been a reason for a lack of support for the sprawl, especially in communist countries and in the Middle East. For example, in most cities in the East housing is not scattered, which is the result of political decisions.

In general, the urban sprawl has a negative connotation in terms of health, environmental and cultural issues. On the other hand, in past and present articles, planners have focused on the issue of transportation density by comparing two areas. We can determine the miles travelled by people drive to get a main destination (work or school for instance), which means that transportation is another measure related to low-density, as discussed in the next section. In general, most articles have considered these phenomena as very serious issues since world war two, especially in the United States and Germany, as general urban growth was strong, suburbanisation rapid and central city decline precipitous (Conzen 2010).

The most important issue found in numerous articles relates to the differences in measuring the sprawl. Old and new methods have been used to investigate the sprawl, but there has not been one perfect attempt to reach one measure. All geographers and planners can be used in the study of sprawling cities. In this paper, the author has reviewed several measures found in some articles to better understand and evaluate the urban sprawl. It can be argued here that most articles investigating the sprawl have mentioned measures in the introductory sections because of its importance.

Methodologies and approaches

A number of attempts have been made to measure the urban sprawl using different scientific methods and approaches. The concept of urban sprawl is broad and confusing so it can be hard to measure it as it has not been accurately defined. In past empirical work, it was conventional to use the notion of metropolitan areas (MAs), while the sprawl should be measured in rural areas. People have used the census bureau defind urbanised areas but using the urbanisation area is not an ideal solution as territories included in urban-sized areas generally have a density of at least 1000 people per square mile. The map approach has also been used

to understand such a dynamic phenomenon as the urban sprawl, which requires land use change analyses. Furthermore, GIS have been used to generate various thematic layers of the world map, such as roads or railway. Also, satellite images have been studied to identify land use class, to examine growth, both qualitatively and quantitatively using the income level of a new household and the number of automobile owners.

The example was using GIS by urban planner and geographer now in the goal is to find means for understanding the future expansion of the city. Satellite images did not exist before the late 1970s and the number of photographers were not sufficient on the study area the more complete source of information or considering urban sprawl through tie seem to be the different maps produce (Saarloos et al. 2009). Each map database describes the land use. The Urban sprawl has to be considered within temporal dimensions to be understood as a process. The quantification of the sprawl measuring the spatial expansion of urban built area leads to first answer the question: how much. Smart growth or the green belt were the two most important approaches used to study the sprawl, as discussed further in the next section. Also, public transportation as a measure of the sprawl has been based on the notion of density (Richard 1989). However, statistically, the problem with such measure is that they not respond to incremental loss of land resources.

Quantitative and qualitative measures of the urban sprawl

Several researchers have attempted to adopt qualitative and quantitative geography approaches. A number of studies sprawl is not only one indicator but a different indicator called the sprawl index has also been used. The most common measure is the average density in the metropolitan area, MA:

D = P/A, with D referring to the density of the city; an area of the city, P is density of tract.

Metropolitan structure

This is frequently used to measure urban form and focuses on the economy, measuring the population density (Franz et al. 2007).

Sub-metropolitan area

This approach to measure the sprawl generally is adopted by transportation planners who use population to explore transportation behaviour. This model recommends less automobile use among high-density urban areas. In doing so, planners attempt to find out how to best provide access from one point to another (Maier et al. 2006).

Community design

Planners use GIs data to analyse spatial pattern and the urban sprawl at a community scale. This is a new approach because of technical condition (Maier et al. 2006). Urban designers use this method to analyse environment at the area scale. Through this approach, we can observe phenomena such as crime and transport behaviours based on objective and subjective measures (Maier et al. 2006).

Landscape ecology

This approach analyses landscape at different scales. According to this approach, urban growth causes habitat and farmland fragmentation and recommends that urbanisation should be contained. The approach is based on natural landscape and usually not developed for urban use. The approach focuses on soil classification and assessment of forestation (Maier et al. 2006). For example, planners measure the sprawl based on two densities-related: the percentage of a metro area population living in urbanised areas and the change in the percentage of the metropolitan population living in urbanised areas between two periods. The disadvantage of this approach is that it depends on density as an indicator of sprawl.

Based on the above descriptions of the methods used to measure the sprawl, it appears that density is one of the most commonly used indicators. For example, geographers, economists, urban planners and designers have studied the urban sprawl in a number of works using the above qualitative approaches. For instance, a sample of such approach has been mentioned by Phelps and Parsons (2003) and Patacchini and Zenou (2009) but in use the case is different.

$$\text{Sprawl Index} = \text{Density Score} - (\text{Strength of Center}) * \text{Distance to Enter Score}.$$

Causes and effects of the sprawl

The urban sprawl and its subsequent infringement on wild land, human and wildlife interaction has become inescapable. In the majority of cases, this interaction has resulted in negative effect for humans, wildlife or both in many countries around the world. Researchers have pointed out many cases to discuss the bad consequences of the urban sprawl, such as Sultana and Weber (2013) who have shed light on the fact that this urban development and its associated negative consequences, such as more travel, greater reliance on cars, absence of public transport, additional use of energy, increased costs in providing utilities and the loss of open space, need to be better understood. Also, the relationship between low density and longer commutes have been examined at the neighbourhood level by researchers (e.g. Handy 1996; Ewing and Cervero 2001). At this scale, low densities reduce the presence of work opportunities in the local environment, thereby producing longer commutes. However, Ewing et al. (2017) examined the effects of density on congestion and commuting time and found no statistically significant relationship between residential density and commuting time although a denser and finer street layout was associated with increased congestion and higher commuting time. More recent commuting research has examined fast-growing areas with low density development (sprawl) and their commuting characteristics. Sultana and Chaney (2003), for example, confirmed that commuting times are highest in areas with low density and recent rapid growth. The authors also found that faster-growing cities have longer commuting times. However, Sultana and Weber (2013) found that low density, fast-growing areas are associated with longer commutes, whether measured by time or miles. The relationship between population density and the mode of transport has been well studied and it has been confirmed that areas with lower population density have fewer journeys by public transport while higher population density has a significant positive correlation with the use of public transport and a significant negative correlation with automobile use (Sultana and Weber 2013).

Accessibility and connectivity

Although researchers said such as Sultana and weber booms in the context of transport technology and showed that construction booms between 1890 and 1960 took place in particular transport eras. In addition to new housing being located farther out from downtown, different housing and neighbourhood forms have emerged and change the demographic or architectural styles. Each housing boom was based on the availability of different transport systems, but still accessibilities. Other measures, used by the most recent papers to measure the sprawl, are very important measures to distinguish between the sprawl and another development pattern that relates one point to another point.

The concept of accessibility is central to urban economies as poor accessibilities may result from a failure to concentrate development or mix land uses. Many different accessibility measures can be found in the literature such as the study of Hanson and Schwab (1987). Also, measures of accessibility, for example average travel time, vehicle miles and vehicle houses of travel per person, are among the most used measures of accessibility.

Moreover, connectivity is another concept that refers to the ease of getting from one point to another one within the city. Studies on the urban sprawl have considered the commuting cost, which refers only to trips to work (Oueslati et al. 2015). In a sprawling city, connectivity between nodes is considered less because of the distance or due to natural obstacles such as mountains (He et al. 2011).

Feminist critique of the sprawl accessibilities

The urban sprawl ignores certain sociological aspects (Popenoe 1979). Lopez (2004) relates the sprawl with two types of physical cost: environment privation and privation of access. Some research has shown that certain diseases may be related to the sprawl. This ecologic study reveals that urban form may be significantly associated with some forms of physical activity and certain health outcomes (Ewing et al. 2003). Also, Ewing et al. (2003) claimed that more research is needed to refine measures of urban form, improve measures of physical activity, and control other individual and environmental influences on

physical activity, obesity, and related health outcomes. For example, Ewing et al. (2003) cross-sectional analyses suggest that urban form is associated with overweight among US youth. Moreover, Research conducted in Canada has related the urban sprawl with active transportation among 12 to 15-year olds arguing that the relative odds of engaging in at least 30 min of active transportation per day increasing by 24% (95% CI 10–39%) for each standard deviation increase in the urban sprawl score. The level of these relationships proved comparable to those previously reported for adults. In addition, residents of sprawling counties were likely to walk less during leisure time, weigh more, and have greater prevalence of hypertension than residents of compact counties (Ewing et al. 2003). In addition, the results of studies indicate an increased rate of obesity and overweight that may be related to less accessibilities. With respect to these findings, the low level of activity was particularly significant among women subjects who had no or low levels of physical activity. On the other hand, several studies in oversea emphasise on those kinds of risks and the negative consequences of the urban sprawl.

This has resulted in uncontrolled urban sprawl with living conditions reminiscent of those in developing countries. The absence of adequate drainage systems for sewage and rainwater and the lack of properly organised garbage disposal that characterises these sprawl areas constitutes a particularly favourable breeding ground for vector-borne diseases. Thus, implementing measures to control this type of settlement and to relocate people out of the existing sprawl areas constitutes a significant tool to control this epidemiological risk (Lopez 2004).

Also, suggestions were made and techniques proposed to alleviate the sprawl around the world including preventative measures and mitigation techniques, such as financial compensation and other incentive programmes. The other physical cost of the sprawl relates to the privation of accesses to about half of the American public, those who cannot drive, who have been deprived of adequate access to community, facilities and services.

Hence, it seems hard to escape the conclusion that the urban sprawl is an urban development pattern designed *by* and *for* men. Also, if a family has one car, it is likely to be used by the man. A large body of work has been critical of automobile-oriented suburbs due to travel burdens and mobility limitations on women (Sultana and Weber 2013). However, as feminist approaches have highlighted, increased density, land use diversity and public transit provision are more conducive to the needs of women, while the higher travel times and automobile dependency of newer areas in the commuting transition should be followed by improved conditions.

Congestion

The sprawl may have an impact on traffic congestion, though this is somewhat axiomatic, as more travel will translate into more congestion. However, many factors are not equal develop pattern: the level of roadway congestion depends on where travel occurs as well as how much it occurs. At the same time, high densities are associated with high levels of traffic congestion. Sultana and Weber (2013) found that low density and fast-growing areas are associated with longer commutes, whether measured by time or miles. The relationship between population density and modes of transport has been well studied and confirms that areas with lower population density have fewer journeys by public transport while higher population density has a significant positive relationship with the use of public transport and a significant negative relationship with automobile use (Burke 2015).

Study of the urban sprawl and different approaches in the USA and the UK

The urban sprawl in the United States is due to public policies (Resnik 2010) and several researchers have argued that the sprawl is caused by government policies such as highway building, subsidised single-family housing which primarily benefits suburban residents. Research has also showed that different metropolis areas, only 45% of employed people and 38% of the population lies with five miles of the city centre. To show this, Edward has used regression and both employment density and population density (Log [density] = distance from CBD + E) (Baumont et al. 2004).

Planners aim to prevent urban sprawl, for example, by reducing the cost of public services. Smart growth is one of the theories suggested by planners in the United States to avoid low-density. The approach

emerged in 1992 from the United Nations who emphasised on making the city closer, more compact, transit-oriented, workable, bike friendly and including schools. A mixed use of land use and smart growth have many objectives including the development and expansion of public transportation, the preservation and enhancement of natural and cultural resources and the promotion of public health. In recent years, smart growth has been used to provide an alternative development pattern based on a set of principles and strategies that have evolved over time. Generally speaking, in contrast to the traditional anti-growth movements, smart growth does not mean no growth at all, but relates to growing smart by addressing two issues: *where* and *how* development should occur. Also, smart growth is about developing sustainable communities that are good place to live, doing business, working and raising families. This approach is based on the use of certain techniques such as increasing house density along transit nodes, keeping agricultural land and mixing residential and commercial areas. A number of researchers have mentioned ten characteristics of the smart growth approach adopted in the United States such as creating walkable neighbourhoods, mixing land use and providing different types of transportation choice. Nevertheless, there has been much criticism of the smart growth approach in the United States. First it may increase the cost of land and development and hinder the operation of a free market at the local level (Economic Benefits of Smart Growth and Costs of Sprawl: ConservationTools 2000). According to Office there will be an estimated a 50% growth in population by 2050. Another critique relates to the dispersed patterns of urban growth in many metropolitan areas in the end of twentieth century that constituted real challenges for cities including traffic congestion, more pollution from vehicular emissions and loss of agricultural land. The smart growth policy adopted in the United States cities has been significantly and positively associated with the city percentage according to new city planner.

In the United Kingdom, the approach was different and applied low-density research. The *garden city*, for example, is an urban planning method that emerged in 1898 initiated by Howard in the United Kingdom. This approach adopted in the UK and other countries has been applied on the surrounding of the cities by creating greenbelts, with good residential, industrial and agricultural areas. The idea was about having 32,000 people on a site of 2400 ha (Asabere 2014). This approach requires financial investment to buy land and build gardens. Several garden cities have been built based on Howard's idea, such as Welwyn and Letchworth (Fainstein 2003). Moreover, this approach was applied in Germany between 1906 and 1914 with the aim of building a new society based on the idea of the garden city. The first city, advocated by Howard, contained forty-two houses and was ready in 1912. All of the above approaches were suggested to prevent the urban sprawl that captured the natural land rising growth population, especially after World War Two.

Measuring the sprawl using new technology

Many new measurements and approaches can be used to measure the urban sprawl. The use of remote sensing and GIS, for instance, in the study of the urban Sprawl are new important approaches; however, these techniques are not perfect because a great number of researchers have argued that the concept of sprawl is a complex notion to define. As a result, quantification of this phenomenon is rather complicated and sometimes confusing, especially if we use remote sensing data. Dozens of metrics are employed by urban planners and urban administrators in cities, especially in developed countries. Merits and demerits of these measurements and analytical techniques have also been addressed. The urban sprawl can initially be detected by gauging urban growth in many ways. Masek measures the urban growth by using remote sensing and GIS, which are new methods to measure the rates of urbanization (Yuan 2010). Other studies have measured the sprawl in terms of data layers within a GIS to detect patterns of urban sprawl Almeida (2005) by not only measuring the changes of an individual pixel, but also the changes within a framework of a neighbourhood of pixels. Several studies have addressed these issues which have dealt with a diverse range of themes. Basudeb (2012), for example, critiqued the urban growth analysis method claiming that the use of remote sensing in geography shows that the sprawl can be analysed using many new approaches which may vary from case to case.

However, most researchers have emphasised on using the density as new method (e.g. developed density, population density, and housing density).

Therefore, it can be considered that the best approach to characterise the sprawl is to consider the density criterion using GIS as a tool to measure such as buffer, or making the topology of the area that has changed. If the sprawl is considered as a pattern, it is a static phenomenon but if it is a process, the sprawl is a dynamic phenomenon. Certain researchers have considered the sprawl as a static phenomenon whereas some have analysed it as a dynamic one; however, most researchers claim that it is both a dynamic and static phenomenon. The sprawl, as a pattern, helps us understand spatial scattering but as a static phenomenon, areas described as sprawled are typically part of a dynamic urban scene (Basudeb 2012). The dynamics of the sprawl process can be understood from the theoretical framework of the urban growth process. The use of remote sensing and GIs for the analysis of the urban Sprawl to understand urban patterns, dynamic processes and their relationships is a primary objective of urban planning. Remote sensing, although challenged by the spatial and spectral heterogeneity of urban environments (Basudeb 2012), seems to be an appropriate source of urban data to support such studies (Basudeb 2012). With the changing environment, remote sensing tools such as satellite imagery and aerial photographs (EEA 2002) help create considerably more detailed urban maps and offer planners a much deeper insight. In terms of analysing the urban growth, Basudeb (2012) argues that remote sensing technology, especially considering the recent improvements, can provide a unique perspective on growth and land-use change processes. Data sets obtained through remote sensing are constant over great areas and over time and can provide information of a great variety on geographic scales.

The study of urban growth, as a pattern and process, using remote sensing data helps us understand how an urban landscape is changing through time. In the recent years, remote sensing data and geographic information system (GIS) techniques have extensively been used for mapping (to understand the urban pattern), monitoring (to understand the urban process), measuring (to analyse) and modelling (to simulate) the urban growth, land-use, land-cover change and the sprawl. Also, the physical expressions and patterns of urban growth and sprawl on landscapes can be detected, mapped, and analysed by using remote sensing data and GIS techniques. The decision support systems within the GIS can evaluate remote sensing and other geospatial datasets by using multi-agent evaluation (Basudeb 2012), which can also predict the possibilities in the subsequent years using current and historical data.

Also, Almeida (2005) claims that without a universal definition, quantification and modelling of the urban sprawl is extremely difficult. He argues that creating an urban growth model instead of an urban sprawl model allows us to quantify the amount of land that has changed to urban uses as sprawled city and a compact city. Relative measures, in contrast, quantify several attributes that can be compared among cities and among different zones within a city. Many metrics and new statistics have been used to measure the sprawl, generally known as spatial metrics. Spatial metrics are numeric measurements that quantify spatial patterning of land-cover patches, land-cover classes, or entire landscape mosaics of a geographic area (Basudeb 2012). The question is which spatial metrics are most appropriate for the measurement and analysis of the sprawl.

Some researchers have also attempted to measure the sprawl by establishing multi-indices using GIS analysis or descriptive statistical analysis (Basudeb 2012). These indices cover various aspects including population, employment, traffic, resources consumption, architecture aesthetics or living quality. Commonly used indices include the growth rate of a population or the built-up area and the population density or the residential density. The question is to identify the most stringent tools and how effective they are. Basudeb (2012) suggested comparing a wide variety of different metrics for the analysis of the urban growth. He argues for the analysis of the urban growth and sprawl using remote sensing data (Basudeb 2012) and wrestling the sprawl to the ground by defining and measuring an elusive concept. In a working paper, Fannie Mae, pp 1–38 argue that the main problem associated with most sprawl measurement scales is the failure to define the threshold between sprawling and non-sprawling urban areas and that these measures are often inadequate.

In addition, many other researchers have used new methods to measure the sprawl such as stellate images and GIs analysis. For example Furberg and Ban (2008) investigated the urban sprawl in the Greater Toronto area (GTA) between 1985 and 2005 and the nature of the resulting landscape fragmentation, particularly with regard to the Oak Ridges Moraine (ORM), an

ecologically important area for the region. Six scenes of Landsat TM imagery were acquired in the summers of 1985, 1995, and 2005. These images and their texture measures were classified into eight land cover classes with very satisfactory final overall accuracies (93–95%). Analysis of the classifications indicated that urban areas grew by 20% between 1985 and 1995 and by 15% between 1995 and 2005. Landscape fragmentation due to spatio-temporal land cover changes was evaluated (Furberg and Ban 2008).

Figures 1 and 2 illustrate the density changes using GIs map of the area changes in Richmond, Virginia. In general, statistical techniques along with remote sensing and GIs have been used in many urban sprawl studies (Frenkel and Orenstein 2011). Unfortunately, conventional surveying and mapping techniques are expensive and time consuming for the estimation of urban sprawl and such information is not available for many of the urban centres, especially in developing countries. As a result, a growing research interest is being directed to mapping and monitoring the urban sprawl growth using GIS and remote sensing techniques. As remote sensing is cost effective and technologically sound, it is being increasingly used for the analysis of the urban sprawl. However, the measurement and modelling of the urban sprawl using satellite images have not been well studied till data in developing countries.

Discussion

Numerous new approaches can be adopted to measure to the sprawl of a city. Some of these approaches commonly used by urban economists include measuring the average population density. It does not appear to be enough to measure the sprawl in metropolitan areas. Moreover, measuring the sprawl sometimes requires complex Statistics to which planners should pay close attention. A review of the most important articles on the issue of the urban sprawl revealed that no articles mentions the four dimension measures to measure the city sprawl. Therefore, planners and urban economists need further research in this field.

Also, research in the subfield of transportation has been critical of certain approaches used by planners to measure the sprawl. For example, low and compact car density is very important. Hence, planners must do more research in this area because more often he or she uses as one aspect or sign of happened sprawl in metropolitan area. Transporters suggest ideas and methods to determine the car density such as the density of cars on units of an area. It can be argued here that this kind of mathematical-based technique is not sufficient to address and calculate the sprawl in cities. Indeed, many new technologies exist such as the GIS technique using arc mapping, especially network analyses extension. We can use such ideas in GIS.

The following are methods that can be used for measuring the urban sprawl using GIS tools. In the ArcGIS, for example, there are confusion matrix tables from the upper left to the lower right that show no change of land use between two specified years. However, values on the other side of this diagonal line show the land use change. Also, the rows display previous uses while the columns represent the current use of a polygon.

However, this current review of the published articles on the sprawl did not reveal the four-dimension technique to know more about sprawl cities. Let us focus on the four-dimension technique and how this new approach can be used. If we have many layers like a cadastral map for several years, we can use an earlier map and compare it with other cities. The ArcGIS program can overlay some layers about cities, which in turn, allows us to identify the differences between two cities or more. Thus, we are able to know if there is sprawl or not. Nevertheless, this new method is mathematically complex and planners should know the least overlay between two or more layers in different scales. See Figs. 1 and 2 for more information about land use changes as one of the measures used to identify the sprawl.

Conclusion

Over the past century, the urban growth has taken the form of sprawl. A comprehensive review of the urban sprawl is beyond the scope of this paper, but the main conclusion that may be drawn from previous reviews is that this is a broad, multidisciplinary and multidimensional topic that has been looked at from many different points of view and defined in several ways. There is, however, no agreed universal definition of the city sprawl. Also, there is more than one way to measure different urban forms such as the sprawling city. For example, many ways have been used to

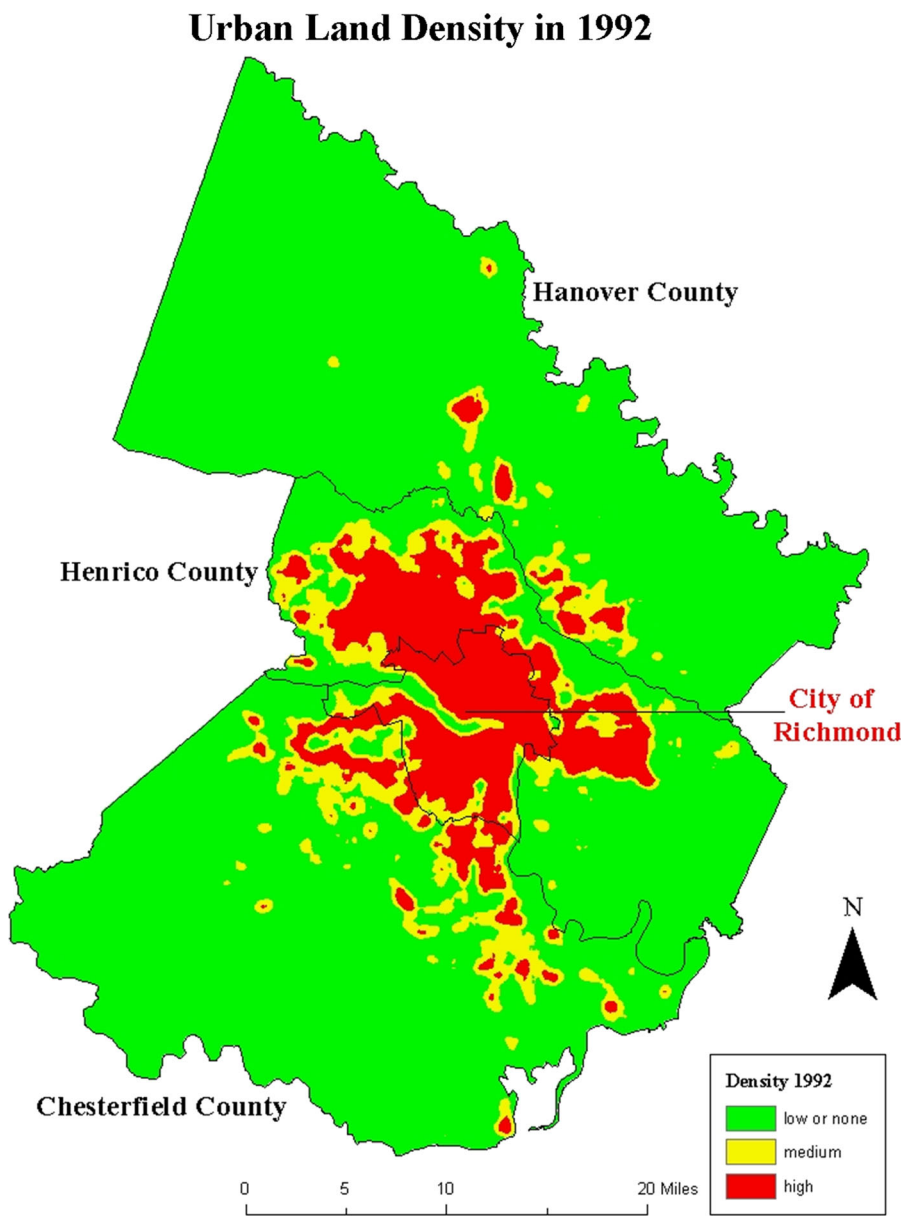

Fig. 1 Density of urban land in 1992 (Almeida 2005)

measure the sprawl such as car density, residential sprawl, or housing sprawl, which may be confusing for those interested in urban form. In many past papers, there have been debates surrounding those issues among urban planners and geographers, because of the different ways to study the sprawl in this urban subfield. ArcGIS, network analyses and static have been used to understand the sprawl as an urban form in past and present studies. Moreover, other techniques could be used to help planners measure the sprawl such as the four-dimension method and other new methods to better understand this phenomenon. These methods include GIs and remote sensing, which are cost effective and technologically sound. That is why they are increasingly being used for the analysis of the urban sprawl. However, the measurement and modelling of the urban sprawl using satellite images with remote sensing data have not been well studied till

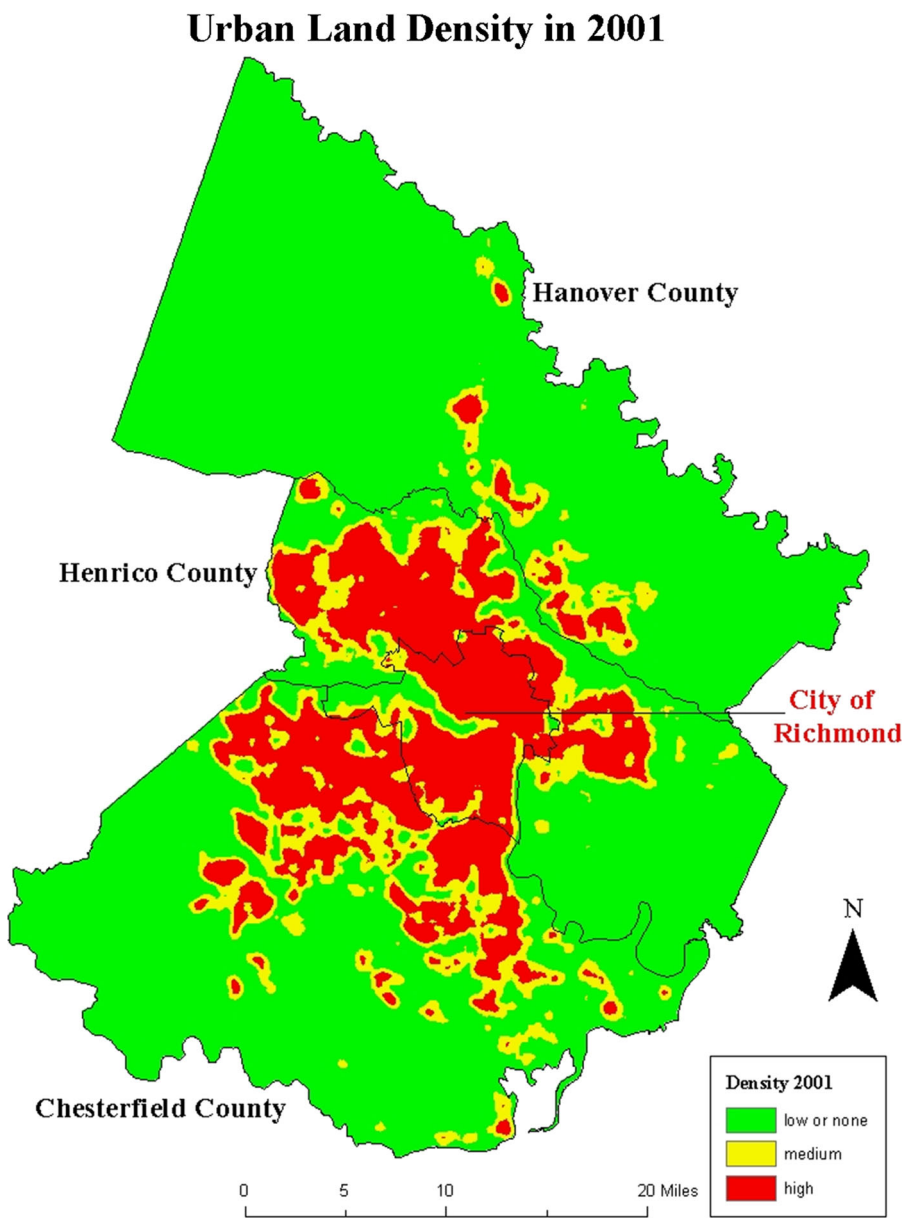

Fig. 2 Density of urban land in 2001 (Almeida 2005)

data in developing countries. Also many ways or methods suggested by researchers, such as developing urban and suburban areas in a more compact manner, may have positive effects and help reduce the negative impact of the sprawl (Banai and DePriest 2014). Also, the smart growth and greenbelt approaches that have been applied in the US and the UK are other good strategies that could be applied in other countries to preserve farmland and open space, decrease auto dependence and relieve the economic burden on local governments. However, many negative effects related to the urban sprawl still remain such as low accessibility, congestion and health and environmental issues. Other critical issues in regard to the urban sprawl, especially for women, relate to the physical cost such as the male-dominated use of the automobile which causes women less accessibility.

References

Almeida, B. S. (2005). *GIS assessment of urban sprawl in Richmond, Virginia*. Blacksburg, VA: Virginia Polytechnic Institute and State University.

Asabere, P. K. (2014). The value of homes in cluster development residential districts: The relative significance of the permanent open spaces associated with clusters. *The Journal of Real Estate Finance and Economics, 48*(2), 244–255.

Banai, R., & DePriest, T. (2014). Urban sprawl: Definitions, data, methods of measurement, and environmental consequences. *Journal of Sustainability Education*. http://www.susted.com/wordpress/content/urban-sprawl-definitions-data-methods-of-measurement-and-environmental-consequences_2014_12/.

Basudeb, B. (2012). *Urban growth analysis and remote sensing: A case study of Kolkata*. Berlin: Springer.

Baumont, C., Ertur, C., & Le Gallo, J. (2004). Spatial analysis of employment and population density: The case of the agglomeration of Dijon 1999. *Geographical Analysis, 36*(2), 146–176. https://doi.org/10.1111/j.1538-4632.2004.tb01130.x.

Bruegmann, R. (2005). Early sprawl, an excerpt from sprawl: A compact history by Robert Bruegmann. http://press.uchicago.edu/Misc/Chicago/076903.html.

Burke, A. (2015). Researchers find correlation between population density, carbon dioxide emissions. *The Daily Free Press*. https://dailyfreepress.com/blog/2015/04/10/researchers-find-correlation-between-population-density-carbon-dioxide-emissions/.

Conzen, M. P. (2010). *The making of the American landscape* (2nd ed.). Abingdon: Taylor & Francis.

Economic Benefits of Smart Growth and Costs of Sprawl: ConservationTools. 2000. http://conservationtools.org/guides/96-economic-benefits-of-smart-growth-and-costs-of-sprawl.

EEA, 2002. Environmental signals 2002. Luxembourg Office for Official Publications of the European Communities.

Ewing, R., & Cervero, R. (2001). Travel and the built environment: A synthesis. *Transportation Research Record, 1780,* 87–114.

Ewing, R., Hamidi, S., Tian, G., Proffitt, D., Tonin, S., & Fregolent, L. (2017). Testing Newman and Kenworthy's theory of density and automobile dependence. *Journal of Planning Education and Research*. https://doi.org/10.1177/0739456X16688767.

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., & Raudenbush, S. (2003). Relationship between urban sprawl and physical activity, obesity, and morbidity. *American Journal of Health Promotion: AJHP, 18*(1), 47–57. https://doi.org/10.4278/0890-1171-18.1.47.

Fainstein, S. S. (2003). *Readings in planning theory* (2nd ed.). Malden, MA: Blackwell.

Franz, M. J., VanWormer, J. J., Lauren Crain, A., Boucher, J. L., Histon, T., Caplan, W., et al. (2007). Weight-loss outcomes: A systematic review and meta-analysis of weight-loss clinical trials with a minimum 1-year follow-up. *Journal of the American Dietetic Association, 107*(10), 1755–1767. https://doi.org/10.1016/j.jada.2007.07.017.

Frenkel, A. & Orenstein, D. (2011). A pluralistic approach to defining and measuring urban sprawl. Urban remote sensing: monitoring, synthesis and modeling in the urban environment. Wiley-Blackwell, Chichester, pp. 165–181.

Furberg, D., & Ban, Y. (2008). Satellite monitoring of urban sprawl and assessing the impact of land cover changes in the Greater Toronto Area. *ISPRS Archives, 37,* 131–136.

Handy, S. (1996). Methodologies for exploring the link between urban form and travel behavior. *Transportation Research Part D: Transport and Environment, 1*(2), 151–165. https://doi.org/10.1016/S1361-9209(96)00010-7.

Hanson, S., & Schwab, M. (1987). Accessibility and intraurban travel. *Environment and Planning A, 19*, 735–748.

He, K., Shi, X., Zhang, X., Dang, S., Ma, X., Liu, F., et al. (2011). Long-distance intercellular connectivity between cardiomyocytes and cardiofibroblasts mediated by membrane nanotubes. *Cardiovascular Research, 92*(1), 39–47. https://doi.org/10.1093/cvr/cvr189.

Iqbal, M. (2005). *Islamic perspectives on sustainable development*. London: Palgrave Macmillan, University of Bahrain, and Islamic Research and Training Institute.

Lopez, R. (2004). Urban sprawl and risk for being overweight or obese. *American Journal of Public Health, 94*(9), 1574–1579.

Maier, G., Franz, G., & Schrock, P. (2006). Urban sprawl. How useful is this concept?.

Ngoran, D. (2014). *Socio-environmental impacts of sprawl on the coastline of Douala: Options for integrated coastal management. Diplom*. Hamburg: Anchor Academic Publishing.

Oueslati, W., Alvanides, S., & Garrod, G. (2015). Determinants of urban sprawl in European cities. *Urban Studies (Edinburgh, Scotland), 52*(9), 1594–1614. https://doi.org/10.1177/0042098015577773.

Patacchini, E., & Zenou, Y. (2009). Urban sprawl in Europe. *Brookings-Wharton Papers on Urban Affairs, 10,* 125–149.

Phelps, N. A., & Parsons, N. (2003). Edge urban geographies: Notes from the margins of Europe's capital cities. *Urban Studies, 40*(9), 1725–1749.

Popenoe, D. (1979). Urban sprawl: Some neglected sociological considerations. *Sociology and Social Research, 63*(2), 255–268.

Resnik, D. B. (2010). Urban sprawl, smart growth, and deliberative democracy. *American Journal of Public Health, 100*(10), 1852–1856. https://doi.org/10.2105/AJPH.2009.182501.

Richard, P. (1989). Review: AREUEA Journal. *Journal of Planning Education and Research, 8*(2), 113–114.

Saarloos, D., Kim, J.-E., & Timmermans, H. (2009). The built environment and health: Introducing individual space-time behavior. *International Journal of Environmental Research and Public Health, 6*(6), 1724–1743. https://doi.org/10.3390/ijerph6061724.

Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 2809–2820. https://doi.org/10.1098/rstb.2010.0136.

Small, K. (2009). Journey to our land, journey to ourselves: Parsha Mase'ei. *Wilderness Torah* (blog). https://

wildernesstorah.org/wilderness-torah/2009/07/17/journey-to-our-land-journey-to-ourselves-parsha-maseei/.

Sultana, S., & Chaney, P. L. (2003). Impacts of urban sprawl on travel behaviors and local watershed in the Auburn-Opelika metropolitan area: A case study on a Small MSA. In *Papers and proceedings of applied geography conferences*.

Sultana, S., & Weber, J. (2013). The nature of urban growth and the commuting transition: Endless sprawl or a growth wave? *Urban Studies, 51,* 544–576. https://doi.org/10.1177/0042098013498284.

Yuan, F. (2010). Urban growth monitoring and projection using remote sensing and geographic information systems: A case study in the Twin cities metropolitan area, Minnesota. *Geocarto International, 25*(3), 213–230. https://doi.org/10.1080/10106040903108445.