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Adopting a policy of sustainable inverse densification in urban sprawl areas

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ABSTRACT

Baghdad City suffers from a continual horizontal urban expansion causing a multitude of urban problems that limit sustainable development. This paper presents an applied study to monitor the stages of urban sprawl of the Al-Zawra area, located on the outskirts of Baghdad City. This study is conducted by following the urban sprawl changes during the period between 2000 and 2020. This study assumes the adoption of the control strategy called urban inverse densification according to the principles of sustainable urban development. The study used the descriptive method and the statistical analytical approach to data extracted from satellite images and topographic maps collected from various sources. The results showed that the population growth distribution indicator in the sprawl phenomenon (Ps) reached 80.71 %, compared to the densification phenomenon (Pd) 13.62 %. While the gross per capita urban land indicator in the sprawl (Ds) reached 19.29 %, compared to densification (Dd) 86.38 %. Therefore, there is an inverse relationship between the population and density indicators and their effect on urban sprawl and urban densification. The results showed the efficacy of an analytical statistical model for rehabilitating urban sprawl areas and reducing pressure on the outskirts of big cities through sustainable inverse densification.

Keywords: Urban sprawl, Densification, Sustainable, Holdren model, Baghdad.

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1. Introduction

Over half of the world's population has been living in cities and towns since 2008. This number is expected to increase to between 70 and 80% by 2050, causing urban degradation and rapid sprawl [1]. The term 'urban sprawl' was first used in an article published in The Times in 1955 as a negative commentary on the urbanization's situation on the outskirts of London. The definition of the term urban sprawl varies, and some researchers argue that the term is inaccurate [2]. Batty et al. (2003) defined sprawl as 'uncoordinated growth: the expansion of society without regard for the consequences, in short, it is an unplanned, gradual urban growth that is often considered unsustainable' [3]. Lopez (2004) defined urban sprawl as the general method of beautification across the vast urban areas of metropolitan cities with high populations [4], while Ross and Dunning (1997) defined it as the mechanism through which density spreads across metropolitan areas [5].
Today, urban sprawl has multiple definitions. Although there is disagreement about the precise definition of sprawl, there is 'a general consensus that urban expansion is characterized by an unplanned and unbalanced growth pattern, driven by many processes and leading to inefficient resource consumption' [6]. It is a process of urban expansion with discontinuous low-density communities, producing mixed fragmented urban areas resulting in chaotic and insecure land usage [7]. Other studies have explained urban sprawl through its

characteristics. Ewing et al. (2002) described sprawl as urban development with at least one of the following characteristics: low-density or single-use growth, sectorial growth, sparse growth, and/or leapfrogs (areas of growth interspersed with vacant land) [8]. This results in the migration of urban residents and jobs to the suburbs using available transportation services. As such, sprawl represents an extension of urban areas towards surrounding rural areas [9]. Conversely, sprawl can be spontaneous or unplanned, with the urban environment gradually encroaching on the outskirts or margins of existing cities [10]. Along with this expansion to the outskirts or edges, another perspective talked about the outlaying and/or infilling of cities' open spaces that can occur with sprawl [11]. Additionally, others classified the morphological patterns of urban sprawl as border sprawl connected with natural or artificial landscapes in a linear expansion, patches of sprawl that occurred in different spatial forms as compared to the surroundings, tentacles along the roadways, fringes, or outskirt sprawl, and the diffuse cluster types [12].The impact of urban sprawl extends from physical damage to land and infrastructure services to the environmental, social, and economic effects. While environmental impacts include green land-cover changes which cause air and water pollution and landscape deterioration, the social impacts include the increase in crime rate and the deterioration of quality of life. Additionally, economic impacts depend on, among other aspects, infrastructure, roads, services, transportation, and the cost incurred by land-use deterioration [13].

As for the urban sprawl in Iraq, it can be said that the Iraqi cities, in general, have undergone tremendous urban pressure as a result of the rapid population growth. Many urban areas and major governorates have suffered from the depletion of social facilities due to informal and unplanned urbanization and the desire for a better life [14]. In addition to the political aspects and the wars, they went through, urban chaos and uncontrolled growth were evident in the basic structures of the cities. As for Baghdad, the development plans and masterplans have stopped since 1982, and despite the existence of many plans, they have not been implemented [14]–[16].

The methods and reasons for studying the phenomenon of urban sprawl have varied over the years. Some studies have investigated methods for measuring sprawl, whether via statistical models or computational fluid dynamics [17], [18][17]–[21]. Some studies used geographic information system (GIS) or similar tools to deal with the impact of sprawl on urban density, environment, or the changes in land-cover, linking solutions to sustainability and local policies [22],[24]. Additionally, some have negatively linked urban shrinking or decline to sprawl found at the outskirts of cities [25], [26]. The Holdren statistical model, average nearest neighbor (ANN), Shannon entropy, and spatial autocorrelation (Moran) are well-known statistical methods [19]. However, even though entropy indices are very common in urban sprawl, interpretation of such indices is believed to be not conclusive [27]. Four key parameters have been used to compare the urban sprawl: built-up area or urban density, population density or gross population, dynamic changes in spatial expansion or mixed-use ratios, and scattering ratio or compactness rates of urban areas [11], [19].

Holdren (1991) developed a mathematical model for measuring sprawl by determining the horizontal development of cities and marking population growth. This technique allowed the estimation of city development resulting from population growth or the expansion of urban development. What distinguished this method from others is its ability to understand the rate of expansion associated with low population density, the elevated rate of individual land use, and the amount attributed to population growth [28][13], [19].

In contrast, rapid urbanization highlights the urgent need to develop cities that meet residents' demands, focusing not only on identifying problems but also on finding solutions. One solution is to create compact cities through urban densification rather than focusing on urban expansion or urban sprawl [29]. Rogers (2008) sought to make cities sustainable by achieving more densified, compact, better connected, and environmentally friendly urban areas. To accomplish this, he introduced the concept of recycling land and buildings to increase development intensity and stop suburbs sprawling into the countryside [30], [31],[32]. Some research proposed focusing on Brownfield's development to optimize existing services, such as transportation and waste management, and encourage more sustainable lifestyles by providing an opportunity to recycle land, clean up contaminated sites, and help environmental, social, and economic regeneration. This also reduces pressure to build on green lands and helps preserve the countryside[33]. Therefore, city densification focuses on occupying vacant city enclaves to fulfil city requirements without resorting to increasing the area of the city [34]. City densification is defined as increasing the building area and housing density to invigorate the urban economy and sociocultural activities, adjusting urban size and shape, reducing urban sprawl, and achieving urban diversity and vitality by developing the internal economy[35], [36]. As a result, urban densification operations were developed to plan urban growth and increase city capacity by increasing the number of floors, as well as increasing the built-up framework, to achieve reasonable density [37]. However, the negative effects of urban

densification include threats to land that supplies green cover, excessive overcrowding, and increases in land value, all of which make it impossible for cities to function properly [38].
Hence, a dense city is defined as one that has multiple vital centres where social and economic activities overlap at centres of attraction; these centres of attraction represent the diversity of activities established in the public transport routes in the vicinity of residential areas. Several strategies have emerged for urban densification policy, such as the vertical cities strategy represented by vertical housing [39], [40], the compact cities strategy represented by dense cities with environmental benefits housing [41], [42], and the smart growth strategy represented by the policy of double intensification for optimal land use. These strategies can also be combined to achieve sustainability and conservation of natural resources[43]–[45]. Densification measurements took different approaches depending on the problem and sprawl types. Some adopted urban scale strategies using a selected criteria and spatial representations like infill, renewal development, or urban containment [46], [47],[48] . As is also the case with sprawl, Landsat mapping is an effective method for addressing urban densities and measuring landcover changes [49].

Understanding the complex relationship between sprawl and densification requires investigating planning at multiple scales, from cities to neighborhoods and households [50].The concepts of urban sprawl and densification are opposite phenomena and can be used as urban indicators to examine suburban and city outskirts areas or the degradation of urban green spaces [38]. Although numerous studies have examined the relationship between urban sprawl and densification [27], [51], [52], others only concentrated on and analyzed the concept of urban densification as a part of urban sustainability [50],[52].
In this research, the term inverse densification was applied to confront the phenomenon of sprawl by going back years in descending order as one of the sustainable development policies. This could be accomplished by either investing the empty properties in the region and reactivating it, or rebuilding existing societies and residential area and improving their environment without prejudice to the vacant lands, as seen in Figure 1. This type was mentioned in many sources and used in several designations[56], [57] .

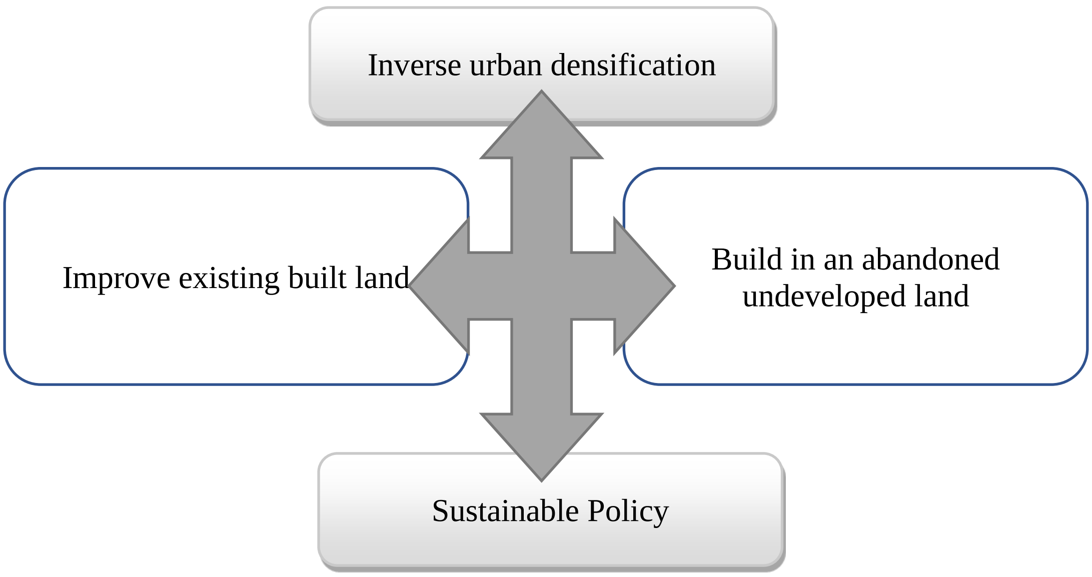


Figure 1. Research concept.

2. Methodology

This study seeks to develop a process for an analytical statistical measurement that incorporates both urban sprawl and urban densification, using city outskirts areas as the study sample. However, the study areas combined several patterns of sprawl, and the solutions were derived based on the planning scale. This study uses the Holdren model to measure sprawl as an existing negative phenomena and inverse densification as part of sustainable urban development solutions in order to address the imbalance caused by urban sprawl. In particular, two indicators were focused on: population growth distribution (P) and density or gross per capita urban land (D), as seen in Figure 2.

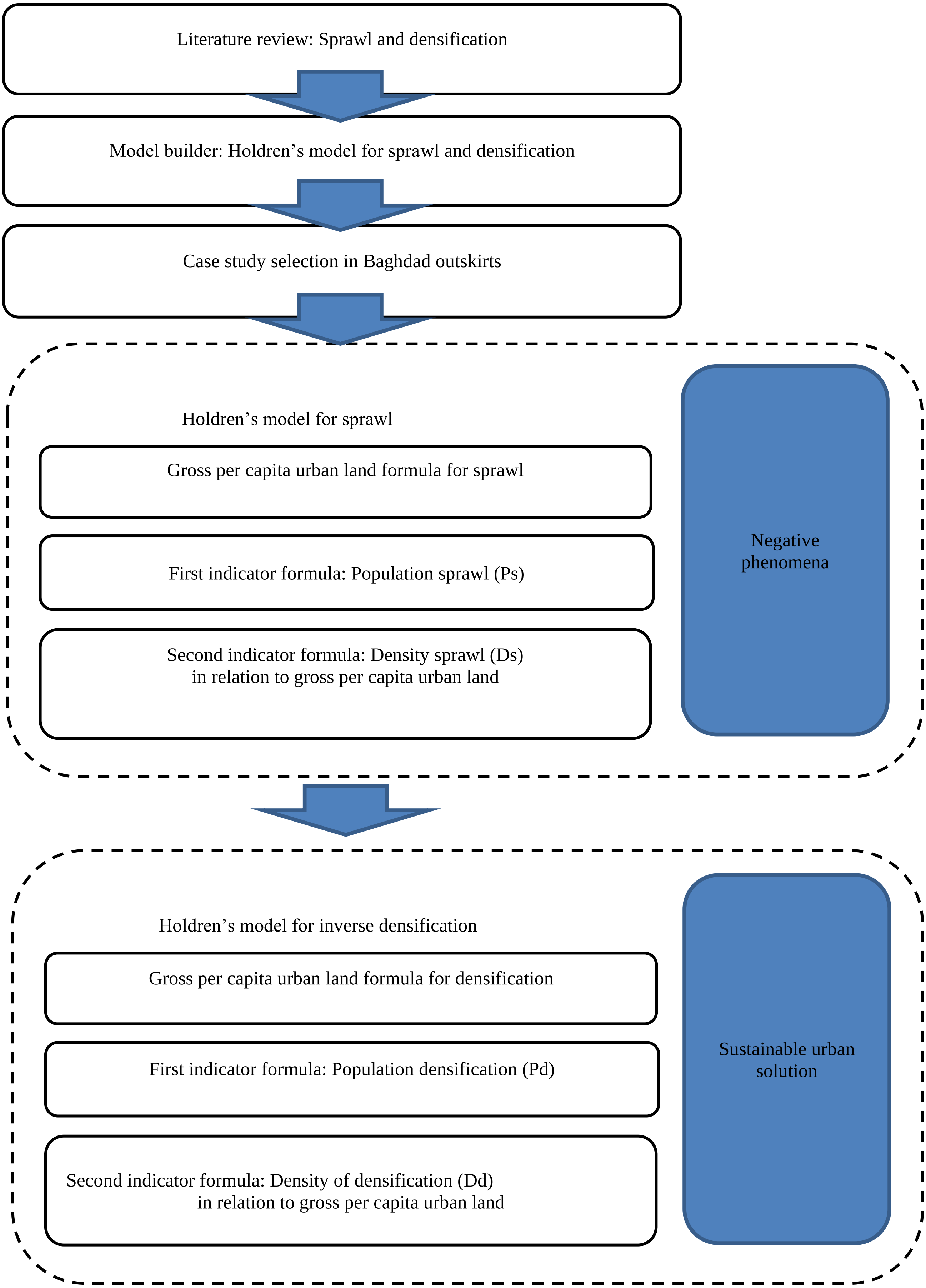


Figure 2. Research framework

3. Material and methods: model builder

Holdren's (1991) model is considered one of the preferred methods for determining the rate of urban sprawl growth. Additionally, it can estimate decrease in population density and rate of decline in population growth [58].

This method can be used to calculate the following:

- The first indicator (P): Population growth distribution and its spread intensity.

It is considered one of the most accurate methods in calculating rates of expansion or restraint of urban lands. In other words, this method can determine the extent of urban development resulting from population growth and measure population outcome from unplanned urban expansion.

- The second indicator (D): Density or the gross per capita urban land.

It is effective in calculating the amount of increased consumption of open lands by calculating the extent of individual share of land consumption[52].

3.1. Urban sprawl calculations

The first step uses equation (1) for the gross per capita land area formula to determine how much of the development of the city resulted from population growth and how much from sprawl urbanization.

$$\boldsymbol{ln}\left(\frac{\boldsymbol{P1}}{\boldsymbol{P0}}\right) + \boldsymbol{ln}\left(\frac{\boldsymbol{A1/P1}}{\boldsymbol{A0/P0}}\right) = \boldsymbol{ln}\left(\frac{\boldsymbol{A1}}{\boldsymbol{A0}}\right) \quad (1)$$ [56],[58]

The second step uses equation (2) to measure the effects of population growth distribution on sprawl (first indicator: Population of sprawl [Ps]).

$$\mathbf{Ps}\,\% = \frac{\boldsymbol{ln}(\boldsymbol{P1/P0})}{\boldsymbol{ln}(\boldsymbol{A1/A0})} \quad (2)$$ [28]

The third step uses equation (3) to calculate the rate of change in population growth distribution (Ps) in relation to gross per capita urban land (second indicator: Density of sprawl [Ds]).

$$\mathbf{Ds}\,\% = \boldsymbol{Eq}\,(\mathbf{2}) \;/\; \boldsymbol{Eq}\,(\mathbf{1}) = \frac{\boldsymbol{ln}\left(\frac{\boldsymbol{P1/P0}}{\boldsymbol{A1/A0}}\right)}{\boldsymbol{ln}\,(\boldsymbol{A1/A0})} \quad (3)$$

P1= Final population
P0= Initial population
A1= Final total area
A0= Initial total area
A1/P1=Final gross per capita urban land
A0/P0= Initial gross per capita urban land
Ps= Population of sprawl
Ds= Density of sprawl

3.2. Urban densification calculation

The first step uses a modification of equation (1) (gross per capita urban land formula) to determine the densification of the city as per equation (4)

$$\boldsymbol{ln}\left(\frac{\boldsymbol{X1}}{\boldsymbol{X0}}\right) + \boldsymbol{ln}\left(\frac{\boldsymbol{E1/X1}}{\boldsymbol{E0/X0}}\right) = \boldsymbol{ln}\left(\frac{\boldsymbol{E1}}{\boldsymbol{E0}}\right) \quad (4)$$

The second step uses equation (5) to measure the effect of population growth distribution on urban densification (first indicator [Pd]: Population of densification).

$$\mathbf{P}d\% = \frac{\ln(X1/X0)}{\ln(E1/E0)} \quad (5) \qquad \mathbf{P}d\% = \frac{ln(D1/D0)}{ln(E1/E0)} \quad .... \textit{Equation } (5)$$

The third step uses equation (6) to calculate the rate of change in population growth distribution (Ps) in relation to gross per capita urban land (second indicator: Density of densification [Dd]).

$$\mathbf{D}d\ \% = \boldsymbol{Eq}\ (\mathbf{5})\ \ /\ \ \boldsymbol{Eq}\ (\mathbf{4}) = \frac{ln(\frac{X1/X0}{E1/E0})}{ln\ (E1/E0)} \quad (6)$$ Dd%=ln(D1/D0E1/E0)ln(E1/E0).............Equation(6)

X1= Final densification population
X0= Initial densification population
E1= Final densification total area.
E0= Initial densification total area.
E1/X1=Final densification gross per capita urban land.
E0/X0= Initial densification; gross per capita urban land
X1-X0= (X) Densification of population
E1-E0= (E) Densification of total area
Pd= Population of densification
Dd= Density of densification
To illustrate the results, these equations produce two indicators (Table 1)

Table 1. Holdren coefficients explaining the relationship between urban sprawl and urban densification [28].

Holdren's coefficients	Expression	Calculations	
First indicator: Population (P)	Population growth distribution	Equation (2) for population of sprawl	Ps
		Equation (5) for population of densification	Pd
Second indicator: Density (D)	The gross per capita urban land	Equation (3) for density of sprawl	Ds
		Equation (6) for density densification	Dd

3.3. Study Area

Al-Zawra is located in the north-eastern part of Baghdad governorate (Figure 3). Even though industrial areas were moved in 1989, many problems resulted in the delay in implementing the essential uses of the land in the proposed master plan. One of these problems is the slum houses. The slums have become not just houses scattered randomly but a clear and significant phenomenon, especially in the study area. Such informal housing threatens and affects land use, especially residential uses. These areas the result of the absence of law enforcement following the fall of Baghdad in 2003. Therefore, this has become an area in the outskirts of Baghdad that contains slums that have subsumed abandoned buildings and vacant agricultural land allocated for a variety of land uses and for which no master plan has yet been implemented. In 2018, due to administrative problems and to improve the level of municipal services in the region, the Ministry of Planning approved the area as a new district within the Baghdad governorate, under name Al-Zawra. [59]- [61].

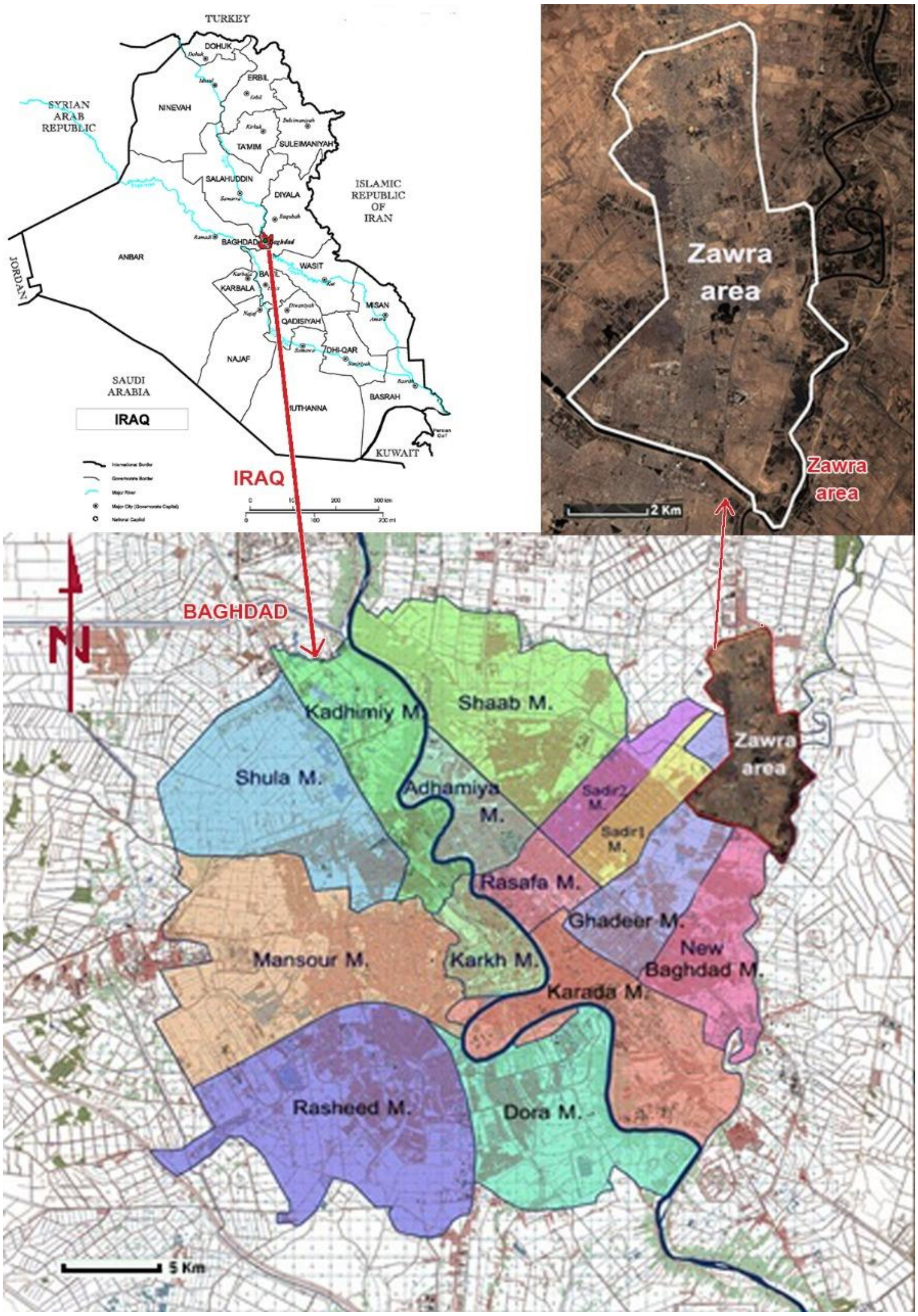


Figure 3. Baghdad City and the Al-Zawra [61]

4. Calculation

The analysis used satellite images, spatial and demographic information from the Municipality of Baghdad and topographic maps and data collected from sources related to the study (in 2000, 2004, 2010, 2016 and 2020). Spatial areas were extracted according to populations spread during these years (Figure 4). The image was modified using the AutoCAD Architecture and Photoshop CC 2017 (version 18), with accuracy depending on satellite images. Calculations were divided into two phases, calculating indicators of urban sprawl and indicators of the urban densification.

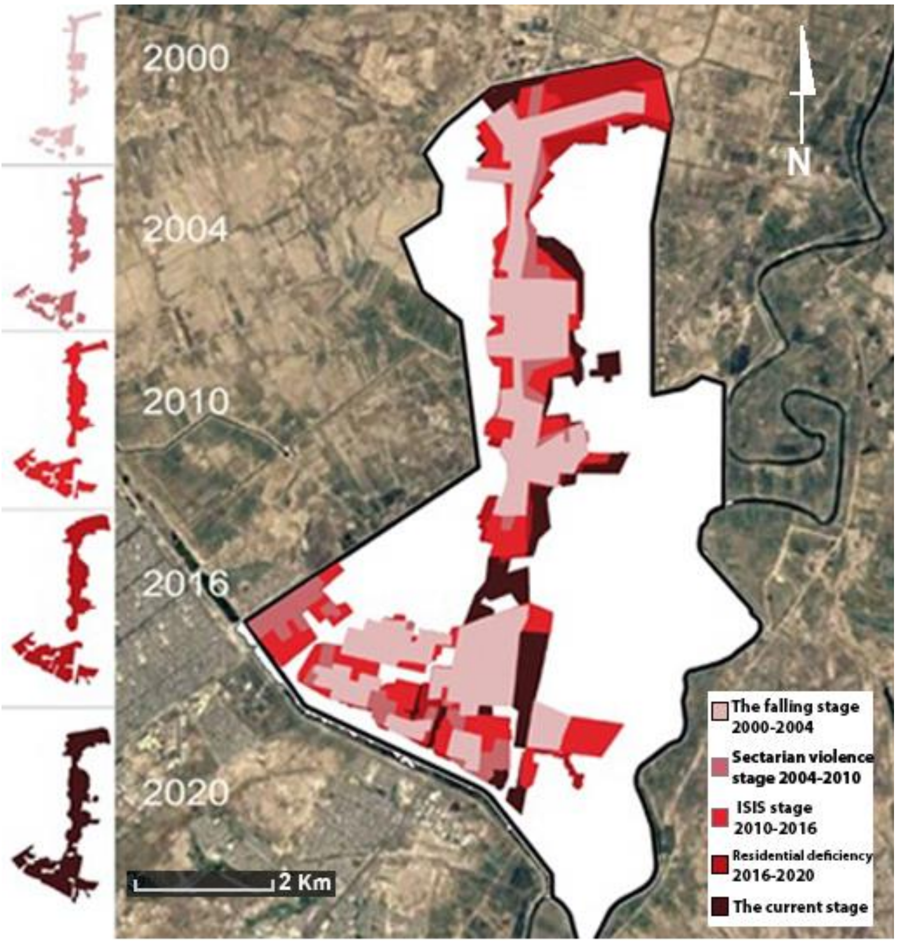


Figure 4. Residential encroachments (in 2000, 2004, 2010, 2016 and 2020)

4.1. First phase: Calculation of Urban Sprawl Indicators (Existing Situation)

Step 1: Gathering Information: (Table 2) illustrates the current spatial and demographic information of the study area

Step 2: Using Holdren's Equation: (Table 3) shows the results of calculations using equations **(**2 and 3) indicating the percentage of the population growth distribution of sprawl (Ps) and the distribution percentage of the gross per capita urban land of (Ds).

Table 2. Spatial and demographic information of Al-Zawra.

Year	Area (ha)	Population (per)	Density (per/ha)
2000	6.21	59527	9586
2004	7.55	66998	8874
2010	11.06	80000	7233
2016	12.36	95524	7728
2020	14.31	107513	7513

Table 3. Calculation of urban sprawl indicators of Al-Zawra.

	A1/A0	P1/P0	A/P	Ln (A1/A0)	Ln (P1/P0)	Ln (A/P)	Ps %	Ds %
2000-2004	1.22	1.13	1.08	0.20	0.12	0.08	0.61	0.39
2004 -2010	1.46	1.19	1.23	0.38	0.18	0.20	0.46	0.54
2010-2016	1.12	1.19	1.07	0.11	0.18	0.07	1.60	-0.60
2016-2020	1.16	1.13	0.97	0.15	0.12	-0.03	0.81	0.19

Step 3: Extracting sprawl indicators: (Table 4) shows a summary of the urban sprawl of the study area the five selected years. The (Table 4) shows the percentage of the population growth distribution of sprawl (Ps) and the distribution percentage of the gross per capita growth in urban land (Ds) due to the absence of planning solution or planning policy controlling urban sprawl (Table 3).

Table 4. Holdren coefficients for population percentage and area density for Al-Zawra urban sprawl

Years	Ps %	Ds %
2000		
2004	60.51	39.45
2010	46.46	53.54
2016	159.59	-59.59
2020	80.71	19.29

4.2. Second phase: calculation of urban densification indicators (prediction situation)

One of the solutions for the rehabilitation of Al-Zawra is sustainable urbanization, using the densification method. This method is based on the idea of a shift from horizontal to vertical expansion. Urban densification is considered a response to a failure to accommodate the urban sprawl and expansion towards the outskirts it aims to address problems caused by demographic changes and increase in land demand making urban areas compact through urban integration policies and densification of residential spaces to preserve land and define minor areas for intensive development within a large area [53]. The following calculations use a hypothetical densification model to rehabilitate the study area in the direction of sustainability.

Step 1: Gathering information: Using data from (Table 2), (Table 5) shows areas of densification and population for the selected years.

Table 5. Total densification areas values (E) and densification population numbers (D)

	(E) densification Total area	(D) densification Population
2020-2016	14.31-12.36=1.95	107513-95524=11989
2016-2010	12.36-11.06=13	95524-80000=15524
2010-2004	11.06-7.55=3.51	80000-66998=13002
2004-2000	7.55-6.21=1.34	66998-59527=7471

Step 2: Using Holdren's Equation: Using equations 5 and 6, the percentage of population growth distribution of densification (Pd) and the distribution percentage of the gross per capita urban land (Dd) was calculated (Table 6).

Table 6. Calculation of urban densification indicators for Al-Zawra, 2020–2000

Years	E1/E0	X1/X0	E/X	Ln (E1/E0)	Ln (X1/X0)	Ln (E/X)	Pd %	Dd %
2020–2016 - 2016–2010	6.67	1.29	5.15	1.90	0.26	1.64	0.14	0.86
2016–2010 - 2010–2004	0.27	0.84	0.32	-1.31	-0.18	-1.13	0.14	0.86
2010–2004 - 2004–2000	0.38	0.57	0.66	-0.96	-0.5540	-0.41	0.58	0.42

Step 3: Extracting the densification indicators: (Table 7) shows a summary of the urban densification results. An adoption of a densification policy requires implementation in several stages from the last sprawl year to the first in order to guarantee completion. (Table 7) shows the three stages of controlling population size, where the distribution percentage of the gross per capita urban land (Dd) for the three stages reach 86%, 86% and 42% respectively. This indicates that controlling population density increase contributes to reducing the consumption of large areas and controlling the extension of services, in addition to providing suitable housing within a specific time plan (Table7).

Table 7. Holdren coefficient calculations for population percentage and area density in the urban densification study area

Years		Pd %	Dd %
2020-2016; 2016-2010	(First stage)	13.62	86.38
2016-2010; 2010-2004	(Second stage)	13.54	86.46
2010-2004; 2004-2000	(Third stage)	56.54	42.46

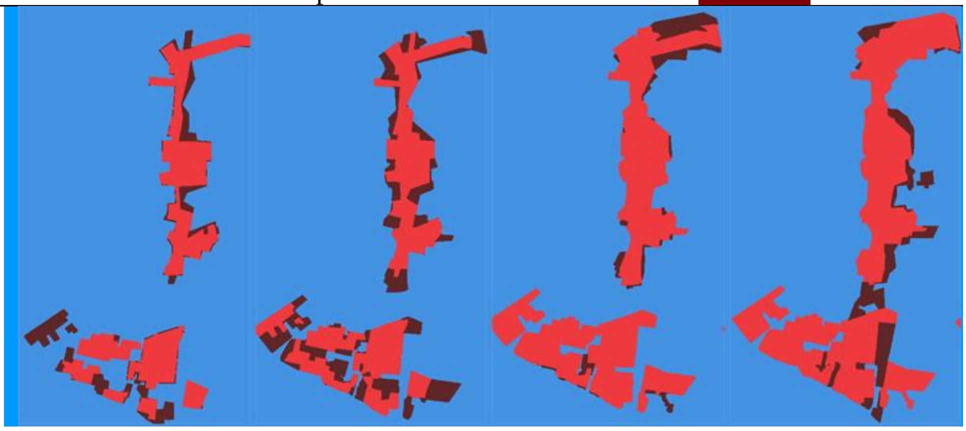
5. Results

5.1. Urban sprawl indicators (existing situation)

The phenomenon of urban sprawl is one of the most crucial problems for the city of Baghdad. Al-Zawra has turned into one of the populous outskirts areas that expanded into slums and urban encroachment. Accordingly, four phases were used to study the urban sprawl in this area, extending from 2000 to 2020, Four plans were outlined for these years indicating the degree of urban sprawl to make a comparison between these years (Table 8). As (Table 4) shows, the percentage of population growth distribution of sprawl (Ps) is irregular and steadily increasing. The measurements percentage of population increased by 60.51% and 46.46% for the years 2004 and 2010 respectively, while it reached 159.59% in 2016. This is a result of the forced migration due to ISIS attacks in several cities and its suburbs. The percentage in 2020 was 80.71%. These results indicate that the area needs to be rehabilitated to cope with the population increase by adopting an appropriate action plan.

Table 8. Summary of changes in urban sprawl changes in Al-Zawra according to the Holdren model (extant situation)

Area of urban sprawl



Activity	Sprawl 2004	Sprawl 2010	Sprawl 2016	Sprawl 2020
From	2000	2004	2010	2016
To	2004	2010	2016	2020
Population of sprawl (Ps)	60.5%	46.5%	159.6%	80.7%
Density of sprawl (Ds)	8,874 p/ha	7,233 p/ha	7,728 p/ha	7,513 p/ha
Actual stage of sprawl	First stage	Second stage	Third stage	Fourth stage

Table 8 and Figure 5 show the abuses that occurred in the study area during successive years, as indicated by the random growth indicators Ps and Ds:

- The sequential reading of the first indicator (Ps: 61%, 46%, 160%, and 81%) reveals that the percentage of population distribution expanded over the years, which indicates that the area has become a focal point for criminals, trespassers, and immigrants. This resulted in the continuation of illegal residential spread and land-use encroachments.
- The consecutive reading of the first indicator (Ps: 61%, 46%, 160%, and 81%) with a corresponding reading for the second indicator (Ds: 39%, 54%, - 60%, and 81% shows the inverse relationship between these two indicators. As the value of the first indicator (Ps) increases, it is offset by a decrease in the value of the second indicator (Ds) (Figure 5). Land-use encroachments lead to economic, environmental, and legal problems due to land shortage. Additionally, this confirms the results of other studies [11].

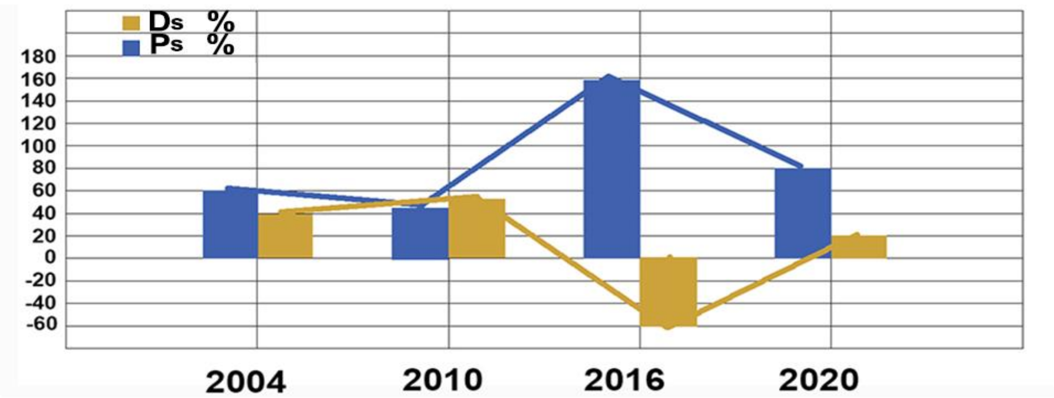


Figure 5. Graphic representation of results according to sprawl ratios

5.2. Urban densification indicators (prediction situation)

Densification is one of solution for sustainable planning addressing urban sprawl that afflicts the outskirts of Baghdad. Accordingly, the study adopted it for avoiding urban sprawl and achieving environmental benefits.
The indicators of densification start from the year 2020 to the year 2000. Therefore, the study divided the densification process into three stages (in reverse and in a descending order), down from 2016, 2010, and 2004, where the density and the percentage of sprawl were calculated for each stage of densification as a predicted process (Table 9). There is an increase in the percentage of population growth distribution of densification (Pd). which was 13.6% in the first densification phase in 2016 and reached 56.5% in the third densification stage in 2004.

A contraction of the population has been achieved. In the first phase of densification in 2016, the distribution percentage of the gross per capita urban land (Dd) was 86.3%, while in the third phase 2004 it was 42.4%. (Figure 5).

Table 9 and Figure 6 show the three stages needed to achieve densification during successive years, as evinced by the measurements of the urban densification prisms (Pd and Dd):

- The consecutive reading of the first indicator (Pd: 14%, 14%, and 58%) indicates that there is a process by which the lands that are to be densified are being controlled.
- The consecutive reading of the first indicator (Pd) with the corresponding reading of the second indicator (Dd) indicate an inverse relationship between these two indicators, as the decrease in the first indicator (Pd) is matched by an increase in the second indicator (Dd).
- The results confirm the efficacy of the process for controlling sprawl, which leads, in turn, to controlling urban land on the outskirts of Baghdad.

Table 9. A summary of the hypothetical study of urban densification in the study area according to the Holdren model.

The area of urban densification

Activity		Densification 2016	Densification 2010	Densification 2004
Duration Time	From	2020	2016	2010
	To	2010	2004	2000
Percentage of population of densification (Pd)		13.6%	13.5%	56.5%
Density of densification (Dd)		8,874 p/ha	9,721 p/ha	1,4240 p/ha
Actual stage of densification		First stage proposal	Second stage proposal	Third stage proposal

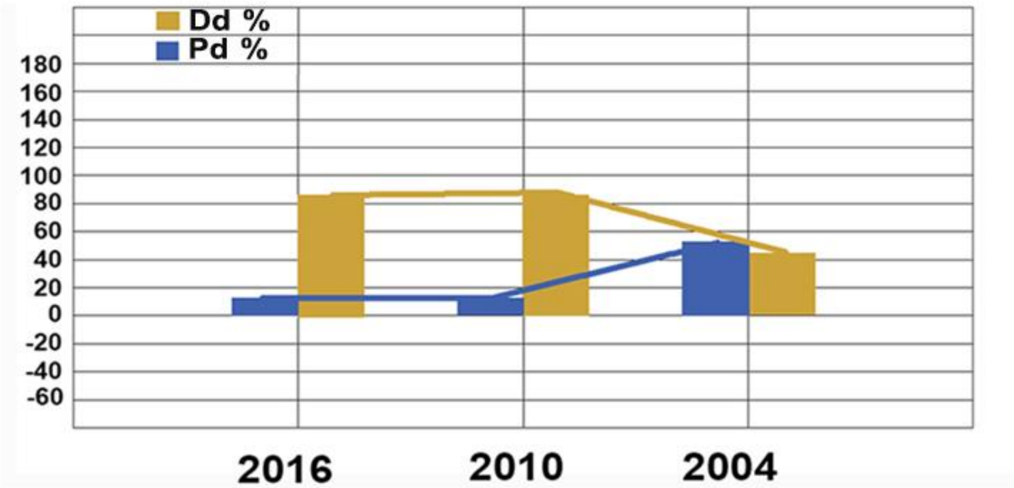


Figure 6. Graphic representation of results according to densification ratio

6. Discussion

Resulted from that

- First, there is an inverse relationship between the two indicators of urban sprawl and urban densification

Ps*Ds=K (constant)
Pd*Dd=K (constant)

- Second, there is an inverse relationship between the indicator of the urban sprawl phenomenon (P*s*, D*s*) and the same indicator the densification phenomenon (P*d*, D*d*).

(Ps) * (Ds) =K constant.
(Pd) * (Dd) =K constant.

As a result of the circumstances experienced by the outskirts of Baghdad in general and the Al-Zawra region in particular between 2000 and 2020, and based on the results of the practical study, the stages were named according to the years as show below, see Figure 4:

The falling stage 2000-2004

Causes of emergence: Before the falling stage, encroachment on buildings and lands began due to the delay in implementing the masterplan and its land-uses. The reasons behind this are the absence of supervision and professionalism, wars, and economic blockade. Encroachments expanded to include all Baghdad neighborhoods.
Stage results: Some farmers (state lands lessors) had illegally divided and resold lands. Additionally, abandoned buildings and vacant agricultural lands were taken over.
Effects on the study area: It is represented by increasing the natural growth of the population and migration towards the outskirts of the city. The percentage of population spread in the study area reached 60.5%, with a sprawl density of 8874 people per hectare. See (Table 2).

The sectarian violence stage 2004-2010

Causes of emergence: At this stage, sectarian fighting and forced displacement led to the migration of 24.2% of the displaced families from the rest of the governorates to the city of Baghdad, specifically to the study area for the year 2007.
Stage results: Represented by the increase in the immigrant population that inhabited Baghdad, which is one of the components of urban sprawl growth of the city.

Effects on the study area: Migration during the period of sectarian violence affected the size and composition of the population through population redistribution and growth the disparity. The percentage of population spread reached 46.5%, with a sprawl density of 7233 people per hectare. (Table 2).

ISIS stage 2010-2016

Causes of emergence: The emergence of ISIS had enormous costs to the Iraqi economy, already suffering from structural problems, as the Iraqi budget deficit increased to 13% in 2015 due to expenditures on the military effort.

Stage results: This, in turn, led to the absence of the state, the weakness of law, and the inability of the official authorities, especially the Baghdad Municipality, to limit or stop the phenomenon of slums and sprawl.
Effects on the study area: The increase in the population in the study area may exacerbate the housing crisis and increase the demand for housing. This resulted in housing deficit and slums became common after the percentage of population spread in the study area reached 159%. (Table 3).

Residential deficiency stage 2016 – 2020

Causes of emergence: The failure of housing policies to develop solutions for the housing problem for the poor left them to find and implement their own solutions. This led to the emergence of social mobility for the transgressors at this stage.
Stage results: This, in turn, resulted in deficiencies of the economic structure and infrastructures and the expansion of areas of decay. This led to social and moral risks that tore apart the social and economic fabric.
Effects on the study area: The exacerbation of the size of the transgressors in the study area resulted in 350,000 people, with a population spread percentage reaching 80.7%. (Table 3).

7. Conclusions

This study provided a comparison between urban sprawl and urban densification during selected years in the outskirts of Baghdad. The relationship between the two indicators (P and D) of the phenomena was analyzed using the Holdren mathematical model. This study contributes to providing an understanding and solutions for the peripheral areas of cities that suffer from urban sprawl, where encroachments and slums are located. The findings revealed a complementary relationship between the two phenomena. The results indicate that urban growth in Baghdad was in a random spread pattern and a strip spread over agricultural land and roads leading to Baghdad. This study addressed the phenomenon of random spread by dealing with its alternative, urban inverse densification. The reason for choosing an inverse densification policy is the possibility of achieving many indicators related to the sustainability of land use, including increasing open spaces, preserving areas and natural resources, encouraging mixed uses, limiting urban sprawl and encouraging compacted expansion. The effect of urban densification emerged by studying the effect of its indicators (population distribution and gross per capita urban land), Three stages of inverse densification were proposed, where an increase in the gross per capita urban land (Dd) was matched by a decrease in population growth distribution (Pd). This study demonstrated the efficacy of using the Holdren model for analyzing the inverse densification for urban sustainability. Suggesting new possibilities in exploring the relationship between urban sprawl and densification.

8. References

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