

An-Najah National University

Faculty of Graduate studies

**Spatial Analysis of Urban Expansion Trends in the
West Bank From 2003 to 2017 Using Geographical
Information Systems**

By

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**This Thesis is Submitted in Partial Fulfilment of the Requirements for
Degree of Master of Urban and Regional Planning, Faculty of
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This thesis was defended Successfully on 05/05/2019 and approved by:

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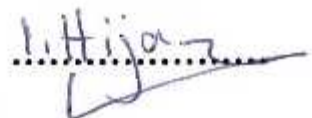
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Dedication

الى كل من ساهم في نجاح هذا المشروع

أهدي عملي المتواضع

Acknowledgment

I would like to express my sincere gratitude to whoever contributed to the completion of this research. First, I would express my deep appreciations for my supervisor Dr. Emad Dawwas for the valuable knowledge and scientific research capabilities I gained through his vision, guidance and patience through the study period.

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الإقرار

انا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

Spatial Analysis of Urban Expansion Trends in the West Bank From 2003 to 2017 Using Geographical Information Systems

أقر بأن ما اشتملت عليه هذه الرسالة انما هو نتاج جهدي الخاص. باستثناء ما تمت الاشارة اليه
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Declaration

This work provided in this thesis, unless otherwise referenced, is the
researcher's own work, and has not been submitted elsewhere for any other
degree qualification

Student Name:

اسم الطالب:

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التوقيع:

Date:

التاريخ:

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List of Abbreviations

WB: West Bank

OPT: Occupied Palestinian Territories

PCBS: Palestinian Central Bureau of Statistics

ARIJ: Applied Research Institute of Jerusalem

UN: United Nations

GIS: Geographical Information Systems

MOLG: Ministry of Local Government

EUA: Extended Urban Area

UA: Urban Area

TIN: Triangulated Irregular Network

DEM: Digital Elevation Model

NNU: An-Najah National Univesity

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Abstract

Urban sprawl in Palestine remains unexplored and the literature on this topic lacks theoretical and empirical evidences. This research aims to investigate if the Palestinian cities in West Bank have exhibited sprawling patterns in their expansion between 2003 and 2017 or not. Moreover, it will empirically and statistically compare these cities for their degree of sprawl. The research further seeks to conceptualize urban sprawl within the Palestinian context.

The study treats urban sprawl as a multidimensional phenomenon rather than a single dimensional, thus a more comprehensive understanding is achieved. The analysis is based on several spatial sprawl indicators stemmed from literature, in which sprawl is analysed both as a pattern and a process. These include indicators of density, spatial geometry, and urban growth indicators. The analysis was mainly conducted using Geographical Information Systems (GIS) and benefited from the powerful spatial analytical capabilities build within this system.

In this research, urban sprawl is measured in relative scales, implying that no threshold between sprawling and non-sprawling development is identified, rather, the analysis will examine if sprawl parameters values increased or decreased during the study period; and

compare the Palestinian urban areas according to their relative degree of sprawl.

Density dimension is quantified through density gradients analysis. The measure allows us to assess the relationship between density and distance from the main urban center and to compare the different urban areas for their process of sprawl. The main findings of the analysis indicate a falling tendency of the density gradient curve during the study period and over distance from the center for all urban areas, with different percentages. The analysis also concludes that densities were all higher in 2017 than 2003.

Urban growth indicators include growth rates of population and builtup area and growth patterns. The output of these measures shows that builtup area growth rates exceeded population growth rates for most of the cities under study, reflecting the tendency of the new development areas towards being more sprawling with time. However, these percentages are varying according to the geopolitical situation of the area and the amount of the politically available land for development. The examination of growth patterns occurring in the urban areas implies that these areas don't follow a specific development trend. Some areas have their infill growth percentages higher than extension or outlying growth; while the majority (7 out of 10 areas) have more extension than in fill growth. Outlying growth has the lowest value among all urban areas.

The spatial geometry of urban form was quantified based on several metrics of complexity and fragmentation of the builtup area, in a total of seven metrics. This analysis notes a varying nature of growth among the urban areas.

After all, the research concludes that all urban areas have qualified sprawl indicators during their growth between 2003 and 2017 with different percentages. It also concludes that there is no specific development trend dominating all urban areas at the same time, and this may be due to the uniqueness of their surrounding geographic circumstances and socio-economic distinctiveness.

Based on the results of the analysis, this research recommends careful and meaningful planning by planners and decision makers on where to allocate the future development, in order to avoid encroaching the agricultural areas and the sensitive environments and avoid putting more pressure on the current infrastructure.

Chapter One

Introduction

1.1 Background and Problem Definition

Urban development processes are represented in a world dominated by cities and urban values (Clark, 1982) and considered as one of the main forces that alter the land cover in the course of time. According to the United Nations, one half of the world's population are expected to live in urban areas by the end of 2025, and for the first time in human history this number is projected to increase to 70% by 2050 (UN, 2008). The continuous agglomeration of people in urban areas causes unguided and unsystematic urban expansion, not only in metropolitan areas, but in the fast-growing medium-size cities and their urban fringes as well (Aguda, et al., 2013). This excessive expansion also known as “urban sprawl” has many negative impacts on society, economy and environment.

The concept of sprawl has its origins in the US context and discussion since the early 20th century, when American cities has excessively and disorderly grown ; whereas European cities had the reputation of having strong urban centres and dominant historical background (Maier et al., 2006). Urban sprawl phenomenon has drawn an extensive attention among scholars, policy makers, and many others, however, the concept still lacks precise meaning or definition.

Over the past decades, thoughts on urban sprawl have been contrasting. There have been those who fought expansion by any and all means, and other who welcomed it and prepared their cities to absorb more residents (Angel et al., 2005). Scholars are also divided between opponents and supporters for sprawl. For example, Ewing supports compact city form (Ewing et al., 2002), whereas Gordon and Richardson support low density development patterns claiming that people prefer to live in dispersed houses seeking calmness and green space (Gordon & Richardson, 1997). Further confusing the issue is the lack of reliable empirical evidence to support the arguments made either for or against sprawl (Longley et al., 2002).

Characterization of urban sprawl varies among different countries due to different societal context, historical backgrounds, and development policies. Thus, the western conceptualization of sprawl cannot be simply transferred to developing countries, and some measurements criteria are neither applicable (Li et al., 2012, Angel et al., 2005)

In Palestine, urban development patterns and forms are directed and shaped by the critical historical and geopolitical situation that prevailed the area for many years. High rates of population growth have also pushed urbanization to be amongst the highest of the world (PCBS, 2012; Shaheen, 2013). This situation; associated with other factors related to unwise planning and weak economics that have contributed to exacerbate the problems associated with urban growth of these communities and make them as unique study areas for urban growth and sprawl.

The exact meaning of urban sprawl within the Palestinian context remains unexplored . While sprawl as a concept still lacks a clear insights of meaning, and the phenomena is a result of many intersecting and complicated factors, many Palestinian scholars have described the development patterns in OPT as sprawling (AbuSada & Thawaba, 2011; Alnoubani, 1995; Abu Helu, 2012; Raddad & Samat, 2016; Sadaqa, 2017), however, these assumptions were neither based on empirical evidences, nor they approached sprawl from a quantitative perspective to support their claims (Dawwas, 2011). Furthermore, the great majority of the aforementioned studies have concentrated on the agricultural impact of urban growth as the main indicator of sprawl, however, urban sprawl has many other dimensions related development patterns and the processes that lead to them over time.

This research will conduct a spatial analysis on urban development patterns of the Palestinian communities in West Bank and analyse their change between 2003 and 2017 in order to examine if these areas are going towards sprawl in their development or not. The analysis is mainly performed using a combination of GIS and different spatial indicators stemmed from universal sprawl research. The judgment on the current development patterns in OPT will be based on the objective empirical results of sprawl indicators. This research will contribute to fill the gap in the existing literature by approaching sprawl from an empirical quantitative manner.

1.2 Significance of the Study

Empirical studies of sprawl contribute to the understanding of the essence of the phenomenon and bringing quantitative knowledge into the discussion (Batty et al., 1999). To quote William Thomson: “When you measure what you are speaking about and express it in numbers, you know something about it, but if you cannot express it in numbers your knowledge about it is of a meagre and unsatisfactory kind” (Cited in Angel et al., 2005)

A thorough review on sprawl literature in Palestine have found that the concept lacks clear insights of definition, magnitude, or spatial character. Besides, sprawl research is bounded to explain the associated causes or impacts, which remain subjective aspects, and don't qualify a comprehensive understanding of the multidimensional phenomenon. Conversely, very limited studies have addressed the spatial and temporal dimensions of the phenomenon. According to this, our study aimed at drawing an enhanced definition of sprawl in Palestine based on the empirical results of this research, and by making use of the international sprawl indicators.

This study will provide planners and decision makers with knowledge and statistical data about Palestinian cities spatial growth patterns, extent and processes in order to assist them to visualise the trajectories and the underlying functions of their cities. Without this knowledge, the practical discussion on urban sprawl and the effectiveness

of a growth management policy remains only in theoretical domain (Klosterman, 1999; Torrens & Alberti, 2000).

The importance of this study comes from the fact that it is one of the few studies to empirically analyse the spatial patterns of urban growth and sprawl in Palestine and compare Palestinian cities with each other, thus, contributes to fill the gap in the existing sprawl literature. The approach of the study is based on the spatial analysis of related geographic data using Geographical Information Systems (GIS) and is applicable elsewhere. The database established by this research including maps, graphs and statistical data tables is another added value for the study. Furthermore, the approach for measuring sprawl, which is developed by this study, can be used as a base for future research and development on this topic.

1.3 Objectives and Scope

This study aims at analyzing the spatial patterns, and processes of urban growth and urban forms for 10 Palestinian Cities in West Bank between 2003 and 2017 using Geographical Information Systems and spatial sprawl indicators, in order (1) to determine whether these communities are going towards sprawl in their development or not, (2) to compare these cities for their pattern of sprawl, (3) and to rank them from the most sprawling to the least sprawling. The study treated sprawl as a multidimensional phenomenon rather than a single dimensional, thus a more comprehensive understanding is achieved. The selected sprawl indicators include density, spatial geometry of urban form, and urban

growth indicators, in which they will be analyzed both as a pattern and a process. The research further seeks to conceptualize and define urban sprawl within the Palestinian context in the light of the motivations and limitations that shaped and directed the Palestinian development processes and based on the empirical results of the analysis.

1.4 Research Questions and Hypothesis

To accomplish the research objectives, the analysis should respond to the following questions:

Main research Question:

To what extent does the new development of Palestinian communities between 2003 and 2017 can be characterized as sprawling? Or in other words, have Palestinian cities gone towards sprawl in their development between 2003 and 2017 or not?

To answer this question, the following secondary questions must be answered:

1. Do density gradients fall over time? Does the distance from CBD affect the new development density?
2. Has builtup area growth occurred at a comparable rate to population growth? What are the types of growth patterns that occurred? Are they infill, expansion or outlying?
3. Have urban areas get more fragmented and complex over time?

For this sake, urban sprawl will be quantified using three spatially discernible dimensions including:

1. Analysing density gradients of buildings for each urban area, which will clarify the extent to which the urban area has a mononuclear development pattern, as opposed to a poly-nuclear development pattern, and allow for the comparisons of the relative degree of sprawl among different cities in a multiple time points, thus allowing for the evaluation of the process of sprawl.
2. Analyzing the temporal dynamics of urban growth by estimating growth rates of population and built-up area to determine if urban growth occurred at a comparable rate to population growth, and determining the types of urban growth occurring in the urban areas to quantify the amount of infill development patterns as opposed to extension or outlying patterns.
3. Analyzing the spatial Geometry of urban form and its change over time by analyzing shape complexity and its change to determine if the urban area is getting more complex or simple over time, and analyzing the built-up area fragmentation to determine if it is getting more dispersed or compact over time.

This research will test the following hypothesis corresponding to each research question:

1. Question 1: The research assumes that density gradients falls over time and have a negative relationship with distance from the urban center.
2. Question 2: This research assumes that (1) large proportion of the new development between 2003 and 2017 is absorbed by unguided densification through the infilling of the already built-up area since there is no enough space for outer expansion, (2) and thus, population growth rates should exceed urban area growth rate.
3. Question 3: Palestinian cities patterns are characterized with irregular , complex urban forms.

1.5 Research Organization

The thesis is consisted of five chapters. Chapter one introduces the research problem, objectives, significance, and research questions. Chapter two gives a detailed theoretical review on urban sprawl, how it's defined and conceptualized throughout the literature, its characteristics, patterns, and main causes and impacts. The chapter also gives an overview on how to operate and measure urban sprawl using sprawl indicators, supported by international empirical studies. The chapter points out some issues related to measuring sprawl and ends by discussing urban sprawl within the Palestinian context and how it is perceived among the Palestinian scholars.

Chapter three introduces the approach, methodology, and the suggested conceptual model to achieve the study objectives. It also defines the study area, the data types, resources, limitations, data preparation, and data analysis. The chapter justifies the determination of the urban boundary for the study and clarifies the rationale behind each selected sprawl indicator and how it is quantified.

Chapter four discusses the results of each calculated sprawl measure and their value change from 2003 to 2017 in order to reveal the process of sprawl. The chapter provides data sheets for each urban area including the values of all sprawl indicators in 2003 and 2017 and a change map . The chapter ends with calculating an overall sprawl value in order to rank urban areas for their relative degrees of sprawl from the most to least sprawling based on three types of rankings,

Including (1) the number of qualified sprawl indicators, (2) the value of indicators in 2017, and (3) the amount of change in these values from 2003 to 2017 .

Finally, Chapter five draws some conclusions from the study and makes some suggestions regarding the future sprawl research in Palestine.

Chapter Two

Literature Review

2.1 Urban Sprawl: Concept and Operation

2.1.1 Introduction

The literature on urban sprawl is lost in semantic wilderness. It confuses its causes, consequences, and conditions (Galster et al.,2001). Throughout history, Urban sprawl has been variously defined; it has been attached to specific patterns of land use, process of development, a cause of negative externality or consequence of land use practices and many others. Sprawl has been denounced on aesthetic, efficiency, equity, and environmental grounds and defended on choice, equality and economic grounds (Galster et al.,2001). It's of an importance to give a detailed theoretical review on urban sprawl, before one can begin any empirical analysis, yet, it is very challenging to encompass the dozens of definitions, indicators or dimensions for urban sprawl.

2.1.2 Definitions of urban sprawl

The phenomenon of urban sprawl is surrounded by conceptual ambiguity. Galester et al., 2001 survey of literature, consistent with the findings of others (Wilson et al., 2003; Sudhira and Ramachandra, 2004; Angel et al., 2007; Siedentop & Fina, 2010; Harvey and Clark, 1965; Bhatta, 2010) yielded no common definition of sprawl neither in everyday language nor in science, however, many policy makers claim to know it when they see it.

It is worth mentioning that opinions on sprawl held by researchers, policy makers, activists, and the public differ sharply (Bhatta, 2010). How sprawl is defined depends on the perspective of who presents the definition (Barnes et al., 2001). It seems that sprawl is used both as a noun (condition) and verb (process) (Bhatta et al., 2010). Some authors make no attempt at definition, while others ‘engage in little more than emotional rhetoric’ (Harvey and Clark, 1965). Others see sprawl as too general concept; “the term has become so abused that it lacks precise meaning and defining urban sprawl has become a methodological quagmire” (Audirac,1990). Wilson et al., 2003 and Galster et al., 2001 argue that the sprawl phenomenon seeks to describe rather than define. One key characteristic of this ongoing debate is its poor empirical foundation. Typically, arguments are based more on assumptions than clear empirical facts. The key reason for this lies in a relatively weak information base provided by the official land use statistics (Siedentop & Fina, 2010).

Although accurate definition of urban sprawl is a debate, a general consensus on much of its characteristics and their associated problems is shared (Sudhira and Ramachandra, 2004; Torrens and Alberti, 2000). Galester et al., 2001 has introduced the different approaches used to define sprawl in literature. In his survey, he concluded that urban sprawl is usually defined by either one or more of the following methods:

1. Defining sprawl by *example*: Los Angeles for instance is often seen as a prototype of sprawl.

2. Defining sprawl by aesthetic judgement: Representatives of this normative approach usually critique the ugly appearance of sprawl. For example: (Peiser, 2001; Torrens and Alberti, 2000).

3. Defining sprawl as the cause of a negative externality: These definitions recognizes sprawl by its social, environmental or economic impacts such as traffic congestion (Zhang, 2004; Black, 1996; Downs, 1999), environmental contamination (Zhang, 2004; The Sierra Club, 1998; Torrens and Alberti, 2000), Income and racial segregation of neighborhoods (Downs, 1998), and the segregation of jobs and housing (The Sierra Club, 2001).

4. Definitions of sprawl as the *consequence of an independent variable* such as bad planning policies (The Sierra Club, 2001; Zhang, 2001; Sudhira and Ramachandra, 2007).

5. Sprawl as a pattern of land development: These types of definitions often describe the physical characteristics of land use functions, such as density, spatial arrangement and configuration. Patterns of sprawl may include for example : *low density development* (Galester et al., 2001; Bhatta et al., 2010) *Ribbon, leapfrog, and scattered development* (Harvey and Clark, 1965; Ewing et al., 1997).

6. Sprawl as a process of development: Sprawl is considered as a dynamic not a static phenomenon. This definition suggests that some part parts of an urban area may pass through a sprawl before they eventually thickening (so they can no longer be characterized as sprawl (Galester et al., 2001).

2.1.3 Summary

The different groups of definitions suggest that there are different forms, types and levels of sprawl (Almeida, 2005). The following table summarize how sprawl is defined among a group of scholars. From the table, we can notice that density dimension is the most discussed among scholars

Table 1: A summary relating the different types of sprawl definitions among a group of scholars

	Land use pattern	Urban form pattern	Process	Causes	Impacts	Aesthetic	Density
Altshuler and Gomez- Ibanez 1993		*					*
Nelson and Duncan, 1995	*	*		*			*
Burgess and Thomas, 1997			*				*
The Sierra Club,1998	*				*		*
Torrens and Alberti, 2000			*	*	*	*	*
Galester, 2001	*		*				*
Peiser, 2001						*	
Ewing et al., 2002,1997	*	*	*		*		*
Hasse, 2002					*		
Wassmer, 2002		*					
Burchell and Galley, 2003		*		*			*
Wassmer, 2005	*						
Sudhira and Ramachandra, 2007		*		*	*		
Wilson et al., 2003					*		
Bhatta, 2010			*		*		*

2.1.4 Characteristics of sprawling development

Urban sprawl characterization varies among different countries due to societal context, historical back grounds, and urban development policies in the region. As a result of the multidimensionality of the phenomenon, a wide set of characteristics are tied with each dimension. The following

table lists the various characteristics of urban sprawl and categorize them based on each relative dimension:

Table 2: The various characteristics of urban sprawl based on each sprawl dimension

Dimensions	Characteristics
pattern	<p>Low density, Single family residential subdivisions with scattered units (Transportation Research Board,1998; Song & Knaap, 2004; Burchell et al., 1998).</p> <p>Land uses which are spatially segregated (Transportation Research Board, 1998; Burchell et al., 1998).</p> <p>Strip commercial development (Burchell et al., 1998).</p> <p>Scattered (Tsai et al., 2005; Ewing et al., 1997) .</p> <p>Leapfrog development (Tsai et al., 2005; Torrens & Alberti, 2000; Ewing (1994, 1997; Burchell et al., 1998).</p> <p>Spiralling growth outward from existing urban centers (Heimlich & Anderson, 2001; Burchell et al., 1998).</p> <p>Undefined edge between urban and rural areas (Heimlich & Anderson, 2001).</p> <p>Unlimited and non-contiguous development (Transportation Research Board, 1998) .</p>
Impacts	<p>Automobile dependency (Song & Knaap, 2004; Transportation Research Board, 1998; Ewing et al., 1997).</p> <p>Loss of open rural area. (Transportation Research Board, 1998; Burchell et al., 1998).</p>
Causes	<p>Construction by small developers and lack of integrated land use planning(Transportation Research Board, 1998).</p> <p>Fragmentation of governance authority over land uses between many local governments (Burchell et al., 1998).</p>
Process	<p>Urban area growth outpaces population growth (Ewing et al., 1997, 2002, Gordon and Richardson, 1997).</p>
Density	<p>Low-density development (Lee et al., 1998; Tsai et al., 2005).</p>
Aesthetic	<p>Ugly and monotonous development (Peiser, 2001; Burchell et al., 1998).</p>

2.1.5 The spatio-temporal character of urban sprawl

The preceding discussion reveals that sprawl may be defined as a pattern of land development that is a spatial configuration of the built-up environment at a certain point in time, or a process of development, changing its spatial patterns over time. In the first scenario, sprawl is conceived as a static phenomenon (noun), whereas the second scenario

presents sprawl as dynamic phenomenon (verb). The vast majority of scholars shout for considering sprawl both as a pattern and a process simultaneously (Bhatta, 2010).

Sprawled areas are typically part of a dynamic urban scene (Harvey and Clark, 1965; Ewing et al., 1997). The dynamics of sprawl can be understood from the theoretical framework of urban growth process (Bhatta, 2010), to understand this process let's have a look at the hypothetical conceptual representation of growth process made by Herold et al., 2005.

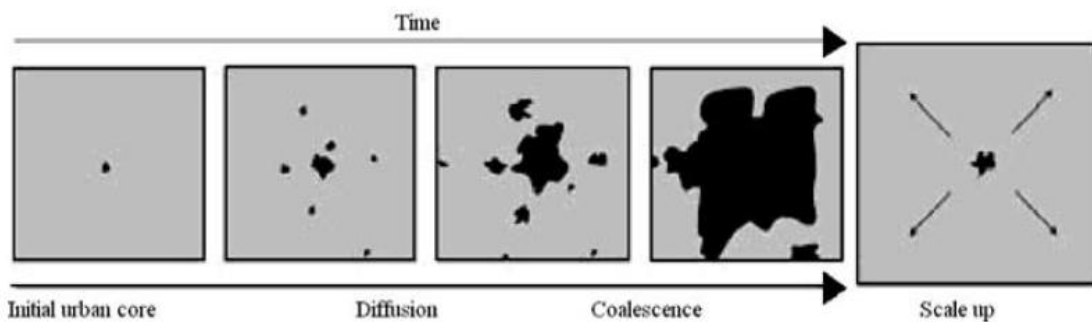


Figure 1: Sequential frames of urban growth (Source: Herold et al., 2005)

Herold points that urban area expansion starts with a *historical core*, then, new dispersed individual cores appears at a distance from the original core as a part of the organic growth and expansion namely as the process of *diffusion*, later with time, these individual cores grow and *agglomerate* thru the development of the empty spaces between the initial urban core and the peripheral centers, so they become one larger core. The new scaled up urban core represents an initial core for a continuum urbanisation at a less detailed zoomed-out extent (Herold et al., 2005). In Traditional urban

studies, this ‘scaling up’ has been represented by changing the spatial extent of concentric rings around the central urban core (Bhatta, 2010).

The previous framework proposes that a sprawl process may precede the formation of a larger contiguous urban patch. However, in this scenario, determining when and where urban sprawl begins is ambiguous. Therefore, sprawl cannot be characterized as a process without considering the pattern, rather, it should be considered as a pattern in the light of multiple temporal process snapshots (Bhatta, 2010). In other words, analysing the respective dimensions of development patterns for an urban area at different times will reveal the process of sprawl (Galster et al., 2001).

2.1.6 Patterns of Urban Growth

Urban growth takes places in substantially different forms. It can take place inside already built-up areas, in vacant spaces or brown fields, at higher densities through the in-fill processes or through “greenfield” development that can either be contiguous with existing built-up areas or can “leapfrog” away from them. It can encroach sensitive environments and it can thus reduce, maintain, or increase open space in and around the city (Angel et al., 2005).

Wilson has identified a three major types of urban growth: *in fill*, *expansion*, and *outlying*, with outlying growth further separated into three categories: *isolated*, *linear* and *clustered* growth (Wilson et al., 2003). The relation to existing developed areas is important when determining the type of urban growth.

In fill development is defined as “all new development between two time points within vacant and open space in already existing built-up area” (Angel et al., 2012). An *extension growth*, sometimes called edge expansion (Forman, 1995) or urban fringe development (Wasserman, 2000), is “all the new development adjacent to the periphery of an existing urban area extending its foot print in outward direction”. *Outlying growth* is characterised by a change from non-developed to developed land-cover occurring beyond existing developed areas or beyond the urban fringe (Wilson et al., 2003). It is broken into three classes: isolated, linear and clustered branch. Outlying growth pattern may generally be considered as urban sprawl.

advocates of sprawl encourage in fill growth to counter sprawl, however, not all in fill growth is considered healthy, a development strategy should study the needed amount of in fill development in an urban area, otherwise, over filling may create congestion, and block the minimum required openness around existing structures.

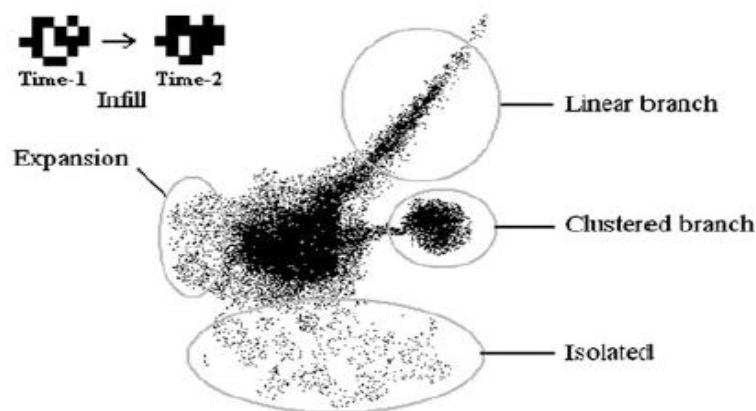


Figure 2: Schematic diagram of urban growth pattern (Source: Bhatta, 2010)

2.1.7 The distinction between urban growth and urban sprawl

The difference between urban growth, urban expansion and urban sprawl is best described by Bhatta et al., 2010, in considering urban growth to be a sum of increase in developed land, manifesting itself in different forms; one of these forms being urban expansion (extension), whereas urban sprawl is expressed as ‘a negative pattern of urban growth’.

From the preceding discussion, we can notice that urban sprawl is a specific type of urban growth. Wilson et al., 2003 has not attempted to characterise sprawl, arguing that creating an urban growth model instead of an urban sprawl model allows users to quantify the amount of land that has changed to urban uses, and lets the user decide what he or she considers to be urban sprawl.

The aforementioned types of urban growth are not all necessarily characterized as sprawl, what is considered as sprawl to someone may not be considered as sprawl for others (Roca et al., 2004, Wilson et al., 2003). In fill growth for example is healthy growth and it encourage compactness, the remedy for sprawl. however, where to draw the line between the economically efficient or inefficient patterns of development is challenging.

2.2 Urban sprawl- Operationalized

2.2.1 Introduction

Measuring the descriptive characteristics of the urban fabric comprises translating these features into meaningful numbers. To quote William Thomson, “When you measure what you are speaking about and express it in numbers, you know something about it, but if you cannot express it in numbers your knowledge about it is of a meagre and unsatisfactory kind”, cited in (Angel et al., 2005).

Quantification of sprawl is really challenging and requires a clear and concise definition, which in this case is non-existent (Wilson et al., 2003; Hasse, 2004). Several indices and methods, both qualitative and quantitative, have been developed to assist planners to spot the occurrence and the features of sprawl in an urban area, however, the multidimensionality of the phenomenon and the wide variety of interested stakeholders have complicated the efforts to measure it.

2.2.2 Sprawl Dimensions

Sprawl dimensions are the basis for quantifying urban sprawl. Some of these dimensions are spatially discernible such as density, land use pattern, or urban form; whereas, other dimensions or characteristics of sprawl are non-spatially discernible, such as aesthetics, causes, or impacts since they incorporate socio economic data or visual qualities that are impossible to delineate in a map of growth (Hasse, 2004).

A review on sprawl research concluded that there are numerous types of analytical approaches to measure sprawl. The early literature concentrated on causes and impacts dimensions of sprawl rather than quantifying its characteristics in a meaningful way. Later, a considerable progress has been made by developing several techniques and measures to quantify the different dimensions of the phenomenon.

Most studies analyse density as a main dimension of sprawl, they calculate different types of densities such as population and buildings density (USA today, 2001). Others analysed the spatial characteristics of urban form or land use patterns of sprawl (Song and Knaap, 2004; Ewing et al., 2002; Galester et al., 2001; Hasse, 2004; Seto and Fragkias, 2005; Yu and Ng, 2007). These studies examine the composition and the configuration of the built-up area by using “spatial metrics”. Another group of scholars measured the non-spatial qualities of sprawl such as studies of the causal factors (Wassmer, 2008; Zhang, 2001), aesthetics analysis (Webster, 1995) which evaluate the built up environment of sprawl, and impact based analysis studies (Siedentop and Fina, 2010; Ewing et al. 2002; Kahn, 2001; Downs, 1999; The Sierra Club, 1998) which quantify the negative ,or positive, impacts of sprawl on the three pillars of sustainability (environment, economy, and society).

Some scholars analyse sprawl as static condition at a certain time point; others suggest that time factor should be taken in consideration when measuring, and the change among the patterns should be detected using at least two different dates; however, the majority of scholars shout for

considering sprawl both a physical pattern and a dynamic process (Bhatta, 2010).

2.2.3 Sprawl Indicators

Sprawl measures- or indices- are mathematical parameters developed by experts to help in quantifying the different descriptive characteristics of sprawl, so they become more comprehensible to user. These measures are also standardized in terms of quantification to facilitate more reliable comparisons among different urban areas (Sim, 2011).

Scholars have developed dozens of sprawl parameters. It is also worth mentioning that single indicator has been developed to multi-dimensional indicator. Each approach has pros and cons; single indicator is easy to quantify but fails to cover all aspects of the complicated phenomenon; multi-dimensional index on the other side is more comprehensive. However, the selection of indicators, and the huge amount of related data is a struggle for scholars (Bhatta, 2010). Of the hundreds of sprawl measures, we concentrate our discussion on the spatially discernible dimensions and their related parameters since they are used in our analysis.

According to (Li, 2012), the indicators raised by western scholars can be grouped into three categories: (1) indicators of urban form , such as continuity, scattering, shape, etc.. (2) indicators of growth ratio, such as growth rate of population versus growth rate of built-up area; and (3) indicators of density, such as population density, dwelling density, employment density , etc... According to Frenkel et al. 2016, most sprawl

measures suggested in the literature can be divided into five major groups: (1) growth indicators, (2) density, (3) urban form, (4) accessibility, (5) and aesthetic measures.

1. Growth indicators

Urban sprawl in its simplest characterization means excessive urban growth, accordingly, most sprawl research start by measuring urban growth rates and the total built up area change as basic measures of sprawl.

- Growth rates of population and built up area: This is a very important measure of sprawl; a black and white hypothesis of sprawl is that if built-up area growth rates exceed population growth rates, then it is an indication of sprawl (Frenkel et al. 2016; Burgess and Thomas, 1997; Bhatta, 2010; Sudhira and Ramchandra, 2004; Ewing et al., 2002; Fulton et al., 2001; Barnes et al., 2001; Gordon and Richardson, 1997).
- Growth patterns analysis: Determining the locations of newly developed areas, through change detection techniques, and figuring whether they are filling in already existing built up areas, extending from the periphery of the existing built-up area boundary or leapfrogging away from this boundary. Outlying patterns of growth are considered sprawl (Wilson et al., 2003).

2. Density indicators

Density is the most common sprawl measure, defined as the ratio between a certain urban activity and the area containing that activity; urban activities

include anything such as population, employees or residential units, etc. Sprawl is defined as a condition of decreasing density over time, or over distance. Possible measures of density include gross population density, net population density, current and expected population divided by developed and developable land, density as a function of accessibility to the CBD, density gradients, and amount of population living in low density (Frenkel et al., 2016).

3. Spatial Geometry of built and open space

Comprises the largest group of sprawl measures adopted from ecological research and fractal geometry. Measures can be grouped in two categories: measures of *composition* and measures of *configuration*:

- *Measures of composition* are concerned with the heterogeneity level of landscape with regard to different patches (or land use parcels in case of urban spatial analysis). They measure the pattern, distribution or the relationship between different land use parcels. Since sprawl is characterized with low levels of land use mix, heterogeneous built up area indicates low sprawl, whereas homogeneous landscape indicates higher sprawl. Examples of composition parameters include number of patches, contiguity, and scatter (Ewing et al., 2002 ; Knaap et al., 2005; Bhatta, 2010; Frenkel et al., 2016; Torrens and Alberti, 2000).
- *Measures of configuration* refer to the geometry of individual land use parcel or built up area, and how regular or irregular their shape is.

Parameters include area, circumference, edge shape, area/circumference ratio and others (Knaap et al., 2005; Frenkel et al. 2016, Bhatta, 2010).

4. Accessibility

This group of measures is used by transportation planners. Poor accessibility lead to higher levels of car usage, thus to higher amounts of sprawl (Ewing et al., 2002). Accessibility parameters may include Mean Proximity Index , the isochrones measurements, gravity indices, utility function index (choice models), and Degree of dependency on private cars index (Frenkel et al., 2016).

5. Aesthetic measures

It is difficult to quantify the aesthetic characters of sprawl objectively unless by consumer preferences or survey sheets. Possible measures include comparing landscapes to certain archetypes of sprawl through automation techniques, standard deviation or photogrammetric approaches. These measures are more relevant to the work of architects or urban designers than urban planners. (Torrens and Alberti, 2000; Frenkel et al., 2016).

The previous approaches, in some cases, do overlap, but the specific use of one approach against the other, depends on the type of data and the system to be analysed. After determining the scale of analysis and choosing among the suitable metrics and methods, sprawl measures can be calculated either as a static condition at one time point or a dynamic condition by

calculating the change of values through a period of time, to quote Galester et al., 2001: “In any event, measuring the respective dimension of development patterns for an urban area at different times will reveal the process of sprawl”.

2.2.4 The use of Geographical Information Systems in spatial analysis

Geographical Information systems (GIS) form a powerful tool for analysing, monitoring, modelling, and predicting the spatial and temporal characteristics of urban growth and sprawl due to its build-in analytical capabilities. GIS allow for visualizing urban sprawl through maps and facilitate in depth analysis for its different patterns and processes (Almedia, 2005).

Different types of spatial queries such a subtraction, modifying, overlaying, union, merge, and spatial join for different types of data layers can be performed in GIS. It is also an extremely powerful tool for creating new data from existing data, it generates slope maps from topographic contour lines and density maps for any event from vector data and their associated attributes and determine the location of the mean center for a group of events. The tool also provides a powerful decision support system for governments and local planning authorities to regulate and assist in future development plans.

GIS can also perform different types of geospatial statistical analysis on geographically referenced data mapped from satellite images with very high precision, through its build-in capabilities and tools named as “spatial

statistics” *. Spatial statistics can conduct many statistical calculations on the locations of features and their accompanying attributes, including analysing spatial distribution, density, patterns, processes and relationships (Arc GIS).

***Note:** Spatial statistics are concerned with spatially referenced data. It is different from spatial metrics that it quantifies sampled data, whereas spatial metrics quantifies the geometry of mapped data. Spatial statistics use the associated values of the variables to group them into spatially homogeneous clusters. They use point data that has been sampled at various geographic coordinates, to analyse a related attribute that is assumed to be continuous among landscape.

2.2.5 Methodological Considerations

According to several authors, there are some issues to be worried about when measuring sprawl, such as scale dependency, boundary sensitivity, data availability, the fact that sprawl is dynamic, measures are static, and the problem of the non-developable area and how to integrate it in sprawl measures (Torrens and Alberti, 2000; Bhatta, 2010; Knaap et al., 2005; Galester 2001).

1. The urban boundary and the modifiable areal unit Problem (MAUP)

Delineation of the urban area boundary has always been a dilemma for urban planners. One of the most factual questions about urban form is: “where does a city end, and the rural area begins?”. This question has no precise answer in the presence of large metropolitan cities that extends in all directions and absorb its surrounding towns and villages in its urban context (Angel et al., 2005).

Urban area is defined by a densely settled central place and the less densely surrounding urban fringes that surround them. (Wassmer, 2005). According to Glaeser et al., 2003, urban center should be defined when measuring sprawl, this center is often considered as the urban area with highest density (CBD).

Most sprawl spatial measures- especially those concerning compactness and dispersion of patterns - are very sensitive to the size of urban boundary of analysis. This problem is an issue of spatial statistics in the analysis of arranged data in zones and known as Modifiable Areal Unit Problem (MAUP) (Bhatta, 2010). A group of points for example, will be classified as clustered if the bounding boundary is too large in size with regard to them. The same group in a smaller boundary will be classified as less clustering, or dispersed, according to the size of that boundary.

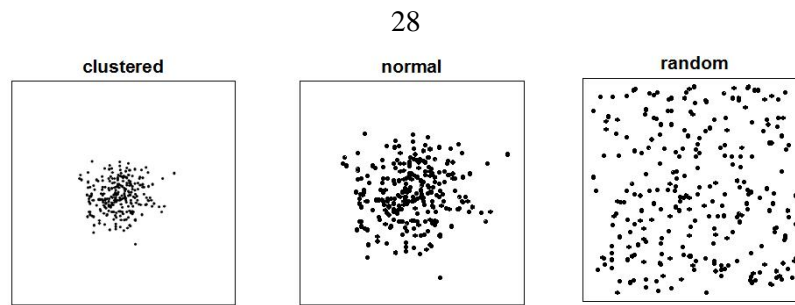


Figure 3: Illustration of the MAUP (Source: GIS- Author edit)

State or municipal boundaries are not always suitable for analysis. In some cities, these boundaries are way larger than the size of the actual built-up area (Angel et al., 2005). Galester et al., 2001 in “wrestling sprawl to the ground” chose the Urbanized Area boundary (UA), defined by US Census Bureau, for their sprawl analysis. UA, which take care of the “over-bounding” problem, don’t solve the problem of “under-bounding” the study area, as some of the urban fringes that should be included are excluded from the analysis. Galester and his group updated their analysis results later using another boundary named “Extended urban area boundary” which took care of both over-bounding and under-bounding issues.

2. Time Factor

As previously discussed, measuring sprawl has a static component that analyse its patterns at a given time point, and a dynamic component, that can be observed by comparing the evolution of the patterns between different points in time. Another question on spatial delineation is raised, whether we should keep the delineation constant or adjusted by the new added urban areas. Adjusting the boundary means comparing two different

cities , while keeping it constant may include or exclude functional parts of the city (Knaap et al., 2005).

3. Selection of indicators

The selection of indicators is usually an expression of the authors' underlying conceptual understanding of sprawl (Siedentop and Fina, 2008). There are other factors affect the selection of measures for analysis, these include the purpose of the study, the dimensions intended for analysis, the scale of observation, and the available data and software.

According to Frenkel et al., 2016, the criteria for good sprawl measurement variables are: objectivity, applicability to different places; appropriateness for multiple spatial scales, meaningfulness, simplicity, and the ease of application.

4. Selection of metrics

Many sprawl metrics correlates with each other. A correlation test was done by Riitters et al., 1995 among 55 different landscape metrics resulting in only five independent factors (cited in Bhatta, 2010). Furthermore, some indicators yield ambiguous and contrary results. Urban areas could be considered sprawled using some measures, yet compact using others (Frenkel and Ashkenazi, 2008; Torrens, 2008 ; Hasse, 2004).

5. Scales of analysis

There are multiple scales at which sprawl can be analysed, the scale of analysis plays a major role in parameters selection. Knaap et al., 2005, in their review on sprawl literature, give an overview on the various scales for measuring sprawl and how several disciplines are associated with them:

Table 3: Scales of Sprawl Analysis

Scale of analysis	discipline	parameters
Metropolitan scale:	Economists	metropolitan density, density variation, distribution (density gradients), and shape.
Sub metropolitan scale	Transportation Planners	density, diversity, accessibility, and transportation network.
Community design	Land Use Planners	relative density, composition, diversity, accessibility, transportation networks and neighbourhood design.
Urban design	Architects	transportation infrastructure, building design, environmental context, accessibility, and perception.
Landscape ecology	Ecologists	patches, composition, diversity, and configuration.

2.2.6 Conceptual model of urban sprawl

The following diagram summarizes the concept and operation of urban sprawl as perceived from literature. The theoretical part (concept) discusses the different dimensions of the phenomenon, while the operation part debates how to empirically measure each of the respective dimensions.

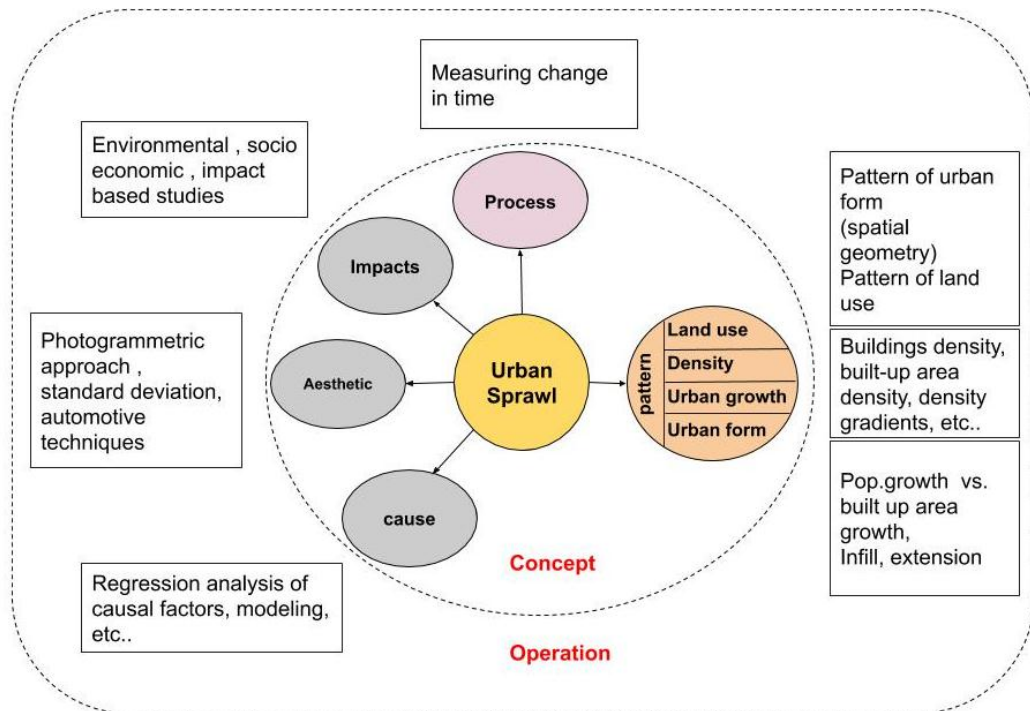


Figure 4: concept and operation of urban sprawl – summary diagram

2.3 The Causes and Impacts of Urban Sprawl

2.3.1 Introduction

The debate over the causes and consequences of urban expansion is elongated. The (cause-effect) relationships between different phenomena are sometimes interrelated. In the case of urban sprawl, it is often hard to distinguish causes from impacts, for example, it is unclear whether the high availability of cars exaggerate *low density* cities, or if *low density* cities emphasises high level of car usage. Furthermore, the consequences of urban sprawl are affiliated with considerable un certainties; what is considered to be sprawl at this moment may not be characterized as sprawl in the future, vacant spaces left by scattered development will soon be filled ; leapfrogging development may be economically efficient, and low

density cities reflect the home buyers preferences for residing in larger units with more access to open space ,away from the crowded city center (Angel et al., 2005; Bhatta, 2010).

Investigating these factors is larger than the scope of this research. However, in-order for this literature to cover the most debated topics on urban sprawl, it is important to shed the light on the main causes and effects of this type of growth.

2.3.2 Causes of urban sprawl

The causes of growth and sprawl are interlinked; however, urban growth doesn't necessarily indicate urban sprawl (Bhatta, 2010). These factors may vary from country to another according to geography or socio-economic situation. According to Angel, the changes in urban form can be attributed to six different factors: demographics, economy, transport system, natural environment, governance, and consumer preferences (Angel et al., 2005).

Demographic factor includes population growth and demand for more living space. *Economic factor* affects urban growth and sprawl significantly; according to location theory, there is a negative correlation between property price and distance from CBD. People choose where to live by trading off the decrease in housing expenditure against the increase in commuting cost with distance, so they move farther from CBD, causing a spatial expansion of the urban area (Geshkov, 2010). Economic factors may include the differences in household incomes and lack of affordable housing, the degree of employment decentralization (Angel et al., 2005),

economic growth, industrialisation, expectations of land appreciation, and housing Investment (Bhatta, 2010).

Another factor leading to sprawl is *governance and policies* including governmental failure to account for the social costs of sprawl such as road congestion, social value of open space, and infrastructure costs of new development (Brueckner et al., 2001). Other governmental factors include legal disputes such as ownership, land speculation , loose regulations of areas outside the main city, poor development policies and lack of proper planning or failure to enforce them and finally, large lot size by using a small proportion of land for development , creating a low-density sprawling development (Bhatta, 2010).

Transportation factors also causes urban sprawl due to the availability of private automobiles and the construction of new highways contributed to linear strip sprawl. factors of *natural environment* such as unsuitable slopes, or sensitive environments are sometimes responsible for discontinuous development (Harvey and Clark, 1965; Barnes et al., 2001; Angel et al., 2005; Bhatta, 2010; Glaser and Kahn, 2004). The final factor in the list is *consumer preferences* for proximity to open space, single-family dwellings, or proximity to one's place of work.

2.3.3 Impacts of urban Sprawl

Urban sprawl debate is often associated with its negative impacts; however, few positive impacts are mentioned (Li, 2009). According to Ewing, sprawl must be judged by its consequences. No development

pattern is integrally good or bad, the impacts of these patterns decide whether to consider them good or bad (Ewing et al., 2007).

The negative impacts of sprawl can be classified into the following categories:

- **Social Impacts :** These are related to deterioration of life quality due to lack of basic amenities and services in sprawling areas (Wilson et al., 2003; Bhatta, 2010), decreased walkability (Ewing et al., 2002) income segregation (Bhatta, 2010), and decreasing social interactions (Siedentrop, 2005).
- **Environmental Impacts such as** high consumption of land per capita (Johnson, 2001; Miller, 2012), landscape fragmentation (Schwick et al., 2012 as mentioned in Thaler, 2014) which make barriers for wildlife habitats and animals , energy inefficiency of automobiles by consuming more fuel in longer trips and causing higher rates of air pollution, increase in temperature caused by the effect of “urban heat island” generated by impervious surfaces and asphalt areas, and impacts on water quality and quantity by reducing the amount of water soaked in groundwater aquifers (Bhatta, 2010).
- **Economic Impacts:** Urban sprawl imposes extra governmental costs on infrastructure maintenance and public services provision (Harvey and Clark, 1965; Siedentop and Fina, 2005; Bhatta, 2010) . These improvements are usually financed by local taxes or user fees which implies additional costs on occupants as well .

- **Transportation impacts:** It is claimed that urban sprawl is a cause of inadequate transportation systems (Bertaud, 2004). In his study, Bertaud compares Barcelona and Atlanta, two cities similar in population but different in densities. He argues that in order for Atlanta to have the same accessibility as Barcelona, new additional 3400 kilometres of metro tracks and 2800 stations should be built; Whereas, Barcelona has only 99 kilometres of tracks and 136 stations. From this, it is clear that higher density cities have more accessibility and less transportation system costs.

Another consequence of urban sprawl is traffic congestion created by suburban residents travelling by their private automobiles towards the center (Kahn, 2000). The research of Ewing 2002 found that sprawling metros exhibited the same levels of congestion delay as other regions, this finding challenges the claim that regions can sprawl their way out of congestion (Ewing et al., 2002).

2.3.4 Positive impacts of urban sprawl

According to scholars, there are few positive impacts of urban sprawl and urban growth in general, these include:

- Higher economic production and increased employment opportunities (Bhatta, 2010 ; Angel et al., 2005)
- Improved public services such as transportation and water supply in the newly developed areas (Bhatta, 2010 , Angel et al., 2005, Wassmer, 2008).
- Lower crime rates and better public schools (Wassmer, 2008) .

- Increased satisfaction in housing preferences , housing affordability (Wassmer, 2008), proximity to green and open space (Ewing et al., 1997; Wassmer, 2008, Thaler, 2014, Angel et al., 2005), and greater housing equality across racial lines(Kahn, 2000; Ewing, et al., 2002). One of the positive arguments for urban sprawl is that some people prefer to live in suburbs farther from the crowded center, while they are still connected to the city by modern transportation systems (Gordon & Richardson, 1997) .
- Relatively short traveling times for those who both live and work in suburbs. In this case, transportation costs may be lower (Siedentrop, 2005).

It is argued that negative effects of sprawl can be reduced or eliminated, air pollution is reduced when both jobs and houses suburbanize, congestion could be decreased by suitable road pricing, and economic agglomeration of activities in city center could also be reduced by sprawl, thus leads to overall economic productivity.

The preceding argument focuses on individuals benefits of sprawl. However, urban sprawl persists its uncoordinated and un controlled style, thus, its negative impacts prevail its positive impacts, and therefore, urban sprawl should be contained.

2.4 Previous Studies

2.4.1 International case studies

Torrens and Alberti 2000 have made remarkable efforts by developing a set of quantitative techniques for measuring some descriptive characteristics of sprawl, however, they have not conducted any empirical analysis, the tools they offered are :

- **Measures of density:** According to this, density decays with increasing distance from the CBD, outward to the fringes along the gradient. It can be measured using density gradients. Indexes for measuring include the quadratic gamma functions (inverse power function and negative exponential function), and equilibrium function.
- **Surface of sprawl:** Measure the continuously changing pattern of sprawl over the entire spatial range of the urban area through kernel density estimation.
- **The geometry of scatter:** Measure the degree of isolation of developed lands. It takes several names like “fragmented, leapfrogging, discontinuous, dispersal, or piecemeal”, and measured by weighed mean distances.
- **The fractal dimension:** A measure of the extent to which a city fills its two-dimensional area using fractal dimension index.
- **Measuring aesthetics:** Measures the architectural configurations and the spatial structure of phenomena through architectonical and

photogrammetric approaches. using the technique of standard deviation, the correlation between pixel “signatures” and sprawl is measured.

- Measuring ecology: Measures the landscape composition (Shannon’s diversity, evenness Index), landscape configuration, etc. Indices include patch density, mean patch size, contagion, interspersion and juxtaposition, and proximity.
- Measuring accessibility: opportunity-based measures, and utility-based measures (spatial choice and decision theory).

Sudhira and Ramachandra, 2004 approach was to study change at the landscape level using GIS to calculate patch density and fragmentation of new growth areas. They used the following indicators to measure urban sprawl in Udupi, Mangalore region:

1. Indicators of Population growth and built-up area: an absolute measure of sprawl is when the rate of built up area growth outpaces the rate of population growth.

2. Indicators of landscape pattern of composition and structure to assess the degree of connectivity of built-up area:

- Shannon entropy: as a measure of the degree of clustering or dispersion of built-up area.
- Patchiness: a measure of the density of patches of all types, the greater the patchiness, the more heterogeneous the landscape is, the lower the sprawl.

- Map density: a measure of compactness of built up area.

3. Indicators of causal factors: Population, population density, annual population growth rate, distance from Mangalore, distance from Udupi.

Gar-OnYeh et al., 2001 used Shannon entropy and GIS to measure the degree of spatial dispersion or concentration of urban form and examine size, shape and configuration of the built-up area. **Yu and Ng, 2007** analysed the spatial and temporal dynamics of urban sprawl in Guangzhou, china, using a combination of both landscape metrics and gradient analysis on remote sensing data, the results reflected the strength of this approach to characterise the complex spatial pattern of urban growth. **Seto and Fragkias, 2005** analysed urban growth of 4 cities in southern china over an 11 years period using spatial metrics. Maps of change were extracted from satellite images for 10 years and urban growth rates were annualized, then, 6 spatial metrics of complexity and size of the urban form were calculated spatially and temporally for 3 concentric buffer zones centred at each of the 4 cities for each year. These metrics include edge density, total urban area, urban patch count, mean patch fractal dimension, average patch size, and patch size coefficient of variation. The study concludes that for comprehensive understanding of urban expansion, a spatiotemporal landscape metrics analysis across buffer zones is an improvement over using only urban growth rates.

The study of the **Angel et al., 2005** entitled “**The dynamics of urban expansion**” examined the dynamics of global urban expansion at the metropolitan scale for 120 metropolitan cities of the world using satellite images and population data for two time periods a decade apart, and several measures of urban extent and expansion (measures of form and shape) were calculated, these measures include: Built up area (Average built up area density), Density (average built up area per person) , contiguity index as a measure of urban spatial structure , compactness index as a measure of the extent to which a city is fully built, and the openness index as a measure of the extent of scattering or compaction of development.

In the study named “Wrestling sprawl to the ground: defining and measuring an elusive concept”, **Galester et al., 2001** has created a composite sprawl index. He defined eight distinct dimensions of land use pattern to be measured. These dimensions were tested for 13 metropolitan areas in US, and the results were only reported for six dimensions. The problem with these dimensions is their complexity and their high data requirements. The eight dimensions of land use pattern included density, continuity, concentration, clustering, centrality, nuclearity, Mixed use, and proximity.

The study area was classified into three types of land use: residential, non-residential or undevelopable due to natural constrains. Galester methodology depends on placing a grid of $\frac{1}{4}$ square mile blocks over the area as units of analysis, then analysing the composition and the spatial

relationship among these grids by calculating the eight measures. According to him, an urbanized area that exhibiting low levels of the eight dimensions is characterized as sprawling, this also suggests that there may be different types of sprawl consisting of different combinations of these dimensions (Galester et al., 2001).

To eliminate “over-bounding” of the study area, Galester used the urbanized area (UA) boundary defined by US Census Bureau instead of using the metropolitan statistical area boundary (MSA); however, UA do not eliminate “under-bounding”. Thus, the same group updated their research results by editing the boundary. The update named with “The Fundamental Challenge in Measuring Sprawl: Which Land Should be Considered,” adds improvement to their previous analysis by developing the (UA) boundary to “the extended urban area boundary” (EUA) in order to take care of the under-bounding problem.

Ewing et al., 2002 have created a sprawl index based on four land use indicators, they assess and compare the degree of sprawl at the metropolitan scale of analysis for 83 metropolitan areas in US using the following metrics: residential density, neighbourhood mix of homes, jobs and services, strength of activity centers, and accessibility of street network: a measure of the size of blocks to capture the extent of streets connectivity.

Ewing used the metropolitan Statistical Area boundary (MSA) taking urban fringes in consideration, however, this method is criticized for over-bounding the study area, thus dramatically skewing the results of the analysis.

Hasse, 2004 measured three residential tracts of development for sprawl at the intra urban level, arguing that the metropolitan level is useful for only comparing metropolitans with each other's, but limited to distinguish spatial details at subdivision level. He developed a set of 12 geospatial measures for analysing sprawl, these measures are grouped into three general categories: Indices of land use **patterns** of sprawl, transportation infrastructure measures of sprawl, and environmental resource impact measures of sprawl.

2.5 Urban Sprawl Within the Palestinian Context

2.5.1 Introduction

Our survey on literature has found a considerable amount of studies debating urbanization in Palestine, by contrast, a lack of studies concerning sprawl is observed. The majority of these studies, neither provide a clear definition, nor support their arguments by empirical evidences. Furthermore, their discussion on urban sprawl is bounded to the relative causes or associated consequences in a subjective manner. Our survey also yielded a scarcity of studies concerning the spatial dimension of the phenomenon, which is a more objective approach to evaluate and understand the magnitude and the process of sprawl in Palestine.

This section will discuss urban sprawl within the Palestinian context, its implications, and its driving forces. We will also investigate how the phenomenon is conceived among scholars. Before proceeding with sprawl debate, it is meaningful to introduce urbanization processes and trends within the motivations and limitations that shaped their character throughout the history of Palestine, in turn, this will contribute to better understanding and recognition of sprawl from other development patterns that have characterized the development processes in Palestine.

2.5.2 Urbanization in Palestine in Perspective

Through the past decades, Palestinians population growth have been amongst the world's highest with an average annual rate of 2.5% (PCBS, 2016) compared to a worldwide annual average of 1.15% (World Bank, 2015), and a high population density approximating 509 person /km² (PCBS, 2018). The rate of urban development has also recorded a peak after 1993 with an average urbanization level of 65% compared to a national average of 50% (Muhsen, 2016; AbuSada & Thawaba, 2011). The rise in urban population is mainly attributed to high rates of natural population growth, internal migrations to urban areas, and annexation of adjacent rural towns to their main connecting cities as a result of urban expansion (Saleh, 2008). Furthermore, a significant number of studies (Khamaisi, 2006; Thawaba, 2009; Shaheen, 2013; Saleh, 2008) have addressed the issue of the rapid urban development in Palestine since early stages and its associated socio-economic and environmental consequences.

2.5.3 Urban development trends in a chronological context

Historically, Palestinian built environment has taken the morphology of a compact traditional structure. Urban settlements were characterized by a dense core, with multigenerational buildings sharing walls to conserve materials and to ensure security. The expansion of urban communities followed a more organized patterns along main road corridor than rural agglomerations which had an organic structure shaped by topography and water resources and were more random in pattern (Ghazi and Shuman, 2005; Muhsen, 2016; Subuh, 2009; Thawaba, 2009).

The current urban morphology of the Palestinian towns is the result of five successive different political regimes. Each regime had its own planning regulations. These include Ottoman empire, British mandate, Jordanian rule, Israeli occupation, and Palestinian authority (Moghayer et al., 2017; Abdelhamid, 2006). Over the past 200 years, these regimes exercised state control over urban growth , land use and planning systems, which affected the development patterns of the Palestinian localities in various ways (Thawaba, 2009). The most prominent features of development patterns of each political era are discussed as follows:

Ottoman period (1850-1917)

The Ottomans had no intention to impose a planning system, however, they introduced different land tenure schemes and a taxation system which represented a quasi-system of land planning (Thawaba, 2009), and left Palestine without future urban plans (coon, 1990).

British Mandate 1917-1948

A comprehensive planning system was introduced for the first time by the British Mandate, including a survey system to foster the creation of a Jewish state in Palestine according to Balfour Declaration. Consequently, the area had witnessed an improved road networks, modern construction methods, and land registration and subdivision process (Cotterell, 1984; Al-Nimr, 1975 as cited in Thawaba, 2009).

The physical development patterns have been affected by the creation of Jewish colonies. Palestinians gathered inside existing towns for security reasons , leading to a considerable growth in buildings number and builtup area which expanded in all directions, and along the main roads. Furthermore, this era was characterized by development on agricultural lands with no restrictions, large minimum lot size, with limitations on site coverage by buildings to serve Israeli occupation goals (Lein , 2002 as cited in Thawaba, 2009).

Jordanian Rule (1948-1967)

Jordanians kept implementing the British planning system while creating new plans for some villages. Their structural plans ignored the future needs of population growth and lacked provincial and regional development strategies (Moghayer et al., 2017).

In this period, Israeli occupation has imposed control over 77% of Palestine. The green line between Jordan and Israel and new security routes have brought several changes to development patterns .Both urban and rural areas have witnessed high growth rates of builtup area and population (Efrat, 1982) expansion beyond the municipal boundaries , and annexation to surrounding satellite towns on the expense of agricultural lands. (Thawaba, 2009).

Israeli Occupation (1967-1994)

This period was characterized by a massive decay in urban development of Palestinian towns. Israeli planning strategies were employed to restrict urban expansion of Palestinians by complicating buildings permits, reducing industrial and economic development, constructing Jewish settlements, land confiscation, and preventing infrastructure provision. The Israeli occupation planning authorities had drawn tight boundaries around Palestinian communities and prohibited expansion outside this line. Sometimes, these lines were defining areas smaller than the actual builtup area, followed by demolishing whatever beyond that boundary (Coon, 1990).

The development patterns of this period were characterized by a decay of the traditional core of the Palestinian town (Grossman 1986), a segregated urban and rural areas (Bahiri, 1989), a ribbon development along the main access roads, and the creation of refugee camps inside the main cities, which has negatively affected their physical spatial structure.

Palestinian Authority (Since 1994)

After signing Oslo agreement in 1993 between PA and Israel, West Bank became under the direct rule of Palestinians, while rural areas remained under Israeli control (Thawaba, 2009). West Bank was further dissolved into 120 disconnected cantons, outside which development is restricted (Coon, 1992). Several partial master plans of Palestinian cities were certified according to Israeli policies that limited their expansion. Neither the existing plans, nor their regulatory framework constitutes a suitable approach to meet the needs of Palestinian future urban development (Moghayer et al., 2017). However, loosening the Israeli restrictions after 1994 has resulted in a significant growth over the available lands and the urban area has almost doubled (ARIJ, 2006).

2.5.4 Challenges to urban development in Palestine

Besides the previous historical factors, there are other challenges to urban development in Palestine that can be summarised as follows:

Demographic factors

Represented in high natural growth rates, accompanied by the scarcity of lands for expansion. This has resulted in pushing the limits of the urban area in a haphazard way (Muhsen, 2016; Shaheen, 2013).

Geopolitical factors

Is considered as the most important and dominant driver of the current development patterns. The unique geopolitical situation has affected the

trends of urban development and expansion. Since the Israeli occupation, WB has witnessed a significant land use change and landscape fragmentation due to political subdivision of land into areas of different jurisdiction (A,B and C), and colonization policies , which turned the area into isolated urban cantons, and constituted as physical constrains for Palestinians expansion . (Alnoubani, 1995; ARIJ, 2004; Khamaisi, 2006; Raddad & Samat, 2016).

In the preparation of the master plans for nearly 400 villages in WB, Israeli planners drew tight outlines around the builtup area of these villages depending on aerial images and neglecting their future expansion needs. Area (A), where Palestinians are allowed to develop without restrictions, constitutes 17.7 % of the WB area only, whereas area (C) which is under the full control of the Israeli occupation government comprises 61% of the WB area (Shaheen, 2013). The creation of separation wall, which took further additional area of the WB, the increasing number of Israeli colonies contiguous to Palestinian towns, and the construction of bypass roads along the perimeter of Palestinian built up areas, put more pressure on Palestinian urban expansion , and contributed to scattered sprawling patterns of development (Moghayer et al., 2017; Muhsen, 2016; ARIJ, 2007; Raddad & Samat, 2016).

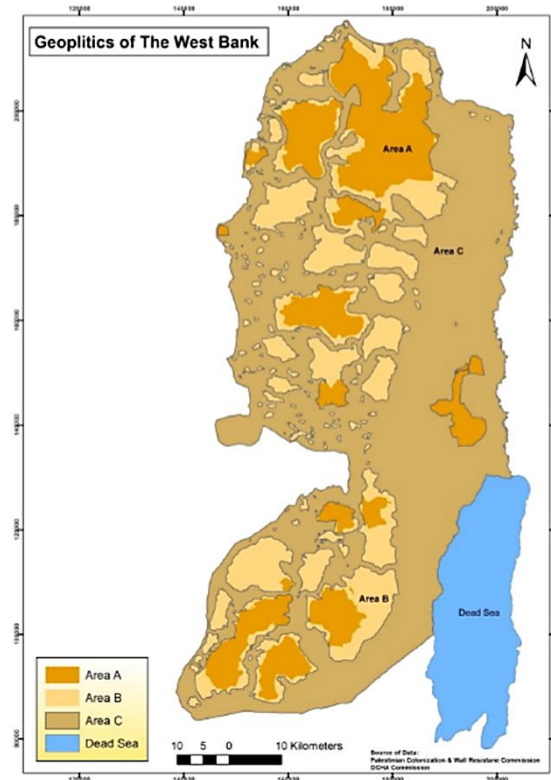


Figure 5 : Geopolitical Land subdivision (Source: Muhsen,2016)

Socio-Economic factors (Abu Helu, I)

- Fleeing cities: people escape the condensed urban centers seeking a more calm and open space for living.
- Consumer preferences: consumers chose to build or buy in suburbs since rents are cheaper and land is widely available.

Institutional factors and planning deficiencies

- The current planning system which is a mixture of all the different planning practises of the several political regimes that have dominated the planning systems in Palestine for more than a century (Abu Helu, 2012).

- Planning and monitoring deficiencies: capacity of planning institutions lacks expertise, control, management and monitoring of the ongoing physical development. Institutional deficiencies include efforts duplication, waste of resources, unclear distribution of responsibilities, the lack of comprehensive future plans, the lack of experts in the field, and the difficulty of implementation and enforcement of these plans (Shaheen, 2013).

When population needs precede government planning, people build in areas that have not been planned yet. This often happens because current plans and laws are outdated and doesn't match future expansion requirements. The new unplanned areas are later annexed to the master plan; however, the government can't change them because they create facts on the ground. Instead, they work on upgrading the services and infrastructure for these areas (Abu Helu, 2012; Subuh, 2009).

- Unbalanced development between urban and rural areas: focusing on certain cities and neglecting others, encourages internal rural -urban migrations, seeking for job opportunities and better lifestyles. This increases pressure on the infrastructure and services of these areas and creates uncontrolled and unplanned growth to absorb the new migrants (Subuh, 2009).

Geographic/physical factors

- High slopes and natural barriers affect the layout of the urban form. These include linear, radial, tree shaped, or concentric urban forms (Abu Helu, 2012).

2.5.5 Implications of urban sprawl in Palestine

Opinions on the beginnings of urban sprawl in Palestine have been inconsistent. According to (Grossman,1986) urban sprawl have started by the end of the British Mandate in 1948, when Palestinian localities experienced extensive changes in their size , shape, and growth rates under the rule of Jordanians. A number of urban settlements witnessed buildings sprawl outside their municipal boundaries over the expense of agricultural areas (cited in Thawaba, 2009). Abu Helu, 2012 suggests that urban sprawl has started during early 1967 when the Israel occupation established new facts on the ground, and 77% of the Palestinian land was occupied. The problem of urban sprawl has aggravated Later in 1993 when urban areas witnessed a significant urbanization bomb after signing Oslo accord and the planning control was transferred to PA over area (A and B) (Alnoubani, 2010). The study of (Muhsen, 2016) has also found that the advent of PA after 1994 has accelerated the urbanization processes, leading to a significant change in urban pattern.

According to Abu Helu, 2012, the current pattern of urban development in Palestine is marked by the spread of informal constructions within urban enclave's fragmentation, unguided densification of urban areas, and change

of use of lands and buildings. The unguided densification and land use change have created consolidated builtup surfaces with an alarming density rates (80% plot coverage), associated with minor setbacks between buildings, loss of privacy, and unhealthy living environment. This situation is frequently observed in Nablus and Jerusalem neighbourhoods for example.

The leap of urbanization after 1994 in area A and B, was also associated with a significant land cover change, and placed an excessive pressure on agricultural lands. According to (Alnoubani, 2010), Palestinian community's expansion is predominantly restricted to agricultural land in Areas A and B. This was accompanied by the emergence of new suburban communities of different sizes, set in isolation from the main builtup area of the city to accommodate the increasing housing demand. This phenomenon is apparent in Ramallah governorate, such as Rawabi, Al-Rayhan, Al-Ghadeer, and Al-Itihad. These new gated communities have taken the form of outlying and isolated pattern of sprawl, which requires the use of private cars, and mainly encroaching agricultural lands. The locations of these communities are within a low proximity to main urban area since real estate sector prefer to invest in cheaper areas to accommodate the income levels of population. Furthermore, these communities were not built according to any governmental development plans; instead, they have been planned, constructed, and supplied with infrastructure by the private sector. (Abu Helu, 2012; Muhsen , 2016).

2.5.6 Literature survey on sprawl in Palestine

A thorough review on sprawl literature in Palestine have found that “urban sprawl” as a concept lacks clear insights of definition, magnitude, and the spatial character. Besides, sprawl research is bounded to explain the associated causes and impacts. Conversely, very limited studies have addressed the spatial and temporal dimensions. Although causes and impacts are important dimensions of sprawl, however, they are still subjective, and don’t qualify a comprehensive understanding of the multidimensional phenomenon. Our survey of literature yielded the following:

- Urban sprawl is often used as an ambiguous “term” describing a negative development pattern, without a clear insight of the pattern, shape, or density.
- Most of the studies mention the term “urban sprawl” in a marginal manner.
- All studies associate urban sprawl with agricultural land decay.
- There is a scarcity of studies conducting spatial analysis on the patterns or the process, or even the magnitude of sprawl according to the international methods of measuring.
- Most studies are concerning Ramallah governorate.

The table below summarize the sprawl dimensions addressed directly or indirectly by Palestinian scholars:

Table 4: Urban sprawl conceptualization among Palestinian scholars

Scholar \ Sprawl Dimension	Pattern	Process	Causes	Impacts	Aesthetic	Density
Thawaba, 2011			*	*		
Sadaqa, 2017	*		*	*		
Al-Noubani, 2009		*	*	*		
Abu Helu, 2012	*		*	*	*	
Muhsen, 2016	*	*	*	*		
Soboh, 2009			*	*		
Kittaneh 2009			*	*		
Raddad & Samat, 2016			*			
Dawwas, 2011	*	*	*			*

It can be noticed that sprawl discussion is restricted to causes and impacts dimensions, while other dimensions are not given the same importance. Density dimension- which is widely considered as the most prominent feature of sprawl is not given a similar importance.

The following table summarizes how sprawl is characterized among Palestinian scholars:

Table 5: Characteristics of sprawl according to Palestinian scholars

Scholar	Sprawl description (character)
Thawaba 2011	Unplanned urban growth that have a negative impact on sustainability
Sadaqa, 2017	Uncontrolled development caused by several factors
Al-Noubani, 2009	A process of transforming the agricultural lands into urban builtup area
Abu Helu, 2012	<ul style="list-style-type: none"> • Irregular, fragmented urban form, • Deteriorating physical and living environment • Haphazard housing development in suburbs • Unplanned , uncoordinated layouts • Structures are products of squatters (informal construction without permits)
Muhsen, 2016	<ul style="list-style-type: none"> • Outlying expansion • Scattered distribution • Isolated patches and outskirts, corridors urban growth area • Changing the rural landscape into rural-urban landscape by encroaching agricultural lands • Urban area growth outpaces population growth
Soboh, 2009	<ul style="list-style-type: none"> • Unplanned ,uncontrolled urban growth, surrounding the main urban areas at suburbs or adjacent to their boundaries caused by several factors • Have a negative impact on agricultural lands.
Kittaneh, 2009	Encroachment on agricultural lands
Raddad & Samat, 2016	Random, unplanned, and unlicensed construction of houses

2.5.7 Local case studies

The study of Emad Dawwas, 2011 entitled as “ Spatio-temporal Analysis of Urban Development Patterns in Palestinian Communities: Bethlehem-Hebron Region (BHR) as a Case” examines the urban spatial development patterns for Bethlehem and Hebron regions between 1995 and 2010 by the use of GIS , remote sensing , and geospatial statistical analysis and modelling. The researcher also analyses the causal factors behind these development patterns.

The researcher has combined a set of indicators on three different spatial scales to determine the amount of infill and suburban development, the amount of development within unbuildable areas, and the average urban densities. The researcher has also investigated the relationship between density and distance from the urban center, and the extent to which the study area can be characterized as sprawling at the neighbourhood level using five land use pattern indicators (density, continuity, concentration, accessibility and centrality).

The study of Mohammad Muhsen, 2016 named "Urban Transformations in the West Bank of Palestine, Drivers and Consequences: a case of Ramallah Area" aimed to analyse the process of urban transformations in Ramallah metropolitan area between 1997 and 2015 and understand its interrelation with the sensitive geopolitical situation on the one hand, and investigate the socio-economic transformations accompanied by this process on the other hand. The study has then analyzed the major spatio-temporal trends and characteristics of urban expansion in Ramallah between 1997 and 2015. Finally, a model for simulating near future scenarios was created.

The researcher used sprawl and growth measures including directional distribution, Urbanization Expansion Intensity Index (UEII), and Landscape Expansion Index (LEI) for determining the type of urban pattern occurring in the landscape (infilling, edge-expansion, and outlying or outskirt). The researcher has also combined the LEI with gradient buffer zone analysis to investigate the trend between the urban area increase and

the distance from the CBD. Shannon entropy was also used as an indicator of urban sprawl.

Our research will concentrate on the spatial pattern analysis of the Palestinian urban areas to determine if their change from 2003 to 2017 indicates urban sprawl or not. Our study is similar to the previous local case studies in that it conducts a spatial pattern analysis using a set of sprawl indicators, however, it will not cover all the aspects that were examined by previous scholars. Instead, the research will address new concepts of analysis by focusing on three pattern components (density, urban growth, and urban form), and doesn't include agricultural or socioeconomic impacts, neither include geopolitical situation and its impact on these patterns. The approach of this research used all of the three spatial dimensions to complement each other in order to understand the complexity of urban sprawl phenomena in a comprehensive way. Furthermore, our study is comprehensive to all Palestinians main cities and their surroundings, thus, making it unique and distinctive from the other studies, and reflecting the comparative nature of the followed approach.

Chapter Three

Methodology and Data Preparation

3.1 Approach and Conceptual Framework of the Study

This research seeks to investigate if the Palestinian cities in West Bank exhibited sprawling patterns in their development between 2003 and 2017 or not. Furthermore, it will empirically and statistically compare the different development trends and the degree of sprawl in each area. The analysis is done based on several spatially discernable sprawl dimensions and indicators defined in literature, in which sprawl will be analyzed both as a pattern and a process. The study treated sprawl as a multidimensional phenomenon rather than a single dimensional, thus a more comprehensive understanding is achieved.

This study employs a quantitative comparative approach to achieve its objectives. Population data, thematic maps and aerial images for two time periods 14 years apart were obtained and analysed, and several measures of urban spatial structure, sprawl indicators, and their change in time, were calculated for 10 cities in West Bank. This was achieved by classifying the urban areas into builtup and non-builtup and associate them with their population in both years using available census data for all the regions comprising the urban areas, then deriving a number of sprawl metrics for each area. These metrics allows to determine if urban areas are going towards sprawling or compaction in their development and allow us to compare these areas for their relative degree of sprawl.

Based on this, urban sprawl within the Palestinian context is identified, and a framework for measuring its manifestations is suggested. The proposed method will measure primary indicators of urban sprawl using Geographic Information Systems (GIS). These include density, growth rates and patterns, and spatial geometry of urban form. These characteristics will be measured in relative scales, meaning that no threshold between sprawling and non-sprawling development will be identified, rather, the analysis will examine if the values of sprawl parameters increased or decreased from 2003 to 2017, and based on this, the transition process from sprawling to non-sprawling, for example, will be determined, and the values will be placed on a continuum from low to high, then the status whether urban areas are going towards sprawling or not will be determined. In other words, this research will compare cities to their relative degrees of sprawl.

3.1.1 Definition of sprawl and selected measures

The selection of indicators is usually an expression of the authors' underlying conceptual understanding of sprawl (Siedentop & Fina, 2010), and the available data. For this study, urban sprawl definition is adopted and modified from Bhatta 2010. It is defined as :

“The less compact outgrowth of a core urban area, exceeding the population growth rate, and characterized by outlying patterns, complex, and fragmented urban forms. Thus, according to this definition, indicators of sprawl were selected to be measured.

The preceding definition is simple; however, it doesn't clearly point out the sprawling development from the non-sprawling. For example, the degree of compactness at which to consider the urban area as sprawling. Nevertheless, this approach gives the researcher a type of a desirable freedom. The degree of compactness, for example, is not similar in all places (Bhatta, 2010). Here, we return to the fact that sprawl characteristics can't be unified, or treated similarly among different places, and the question of the threshold of sprawl can only be answered by theory. Even the most sophisticated indices of sprawl can't overcome the problem of the vague definition of the phenomenon, hence, moving from sprawl to compact form is more likely to be a direction on a continuum rather than a fixed and measurable category (Frenkel et al., 2016). This approach is even adopted by the most advanced sprawl studies, and by this study as well.

Table 6 : The selected sprawl dimensions and indicators

Sprawl Indicator	Sprawl parameter
Density	<ul style="list-style-type: none"> • Density gradients
Growth	<ul style="list-style-type: none"> • Growth pattern • Growth rates of population VS growth rates of builtup area
Spatial geometry	<ul style="list-style-type: none"> • Measures of fragmentation : Scatter , Mean patch size, Number of patches, Shannon entropy , Contiguity • Measures of complexity: Compactness, Fractal dimension, Shape index

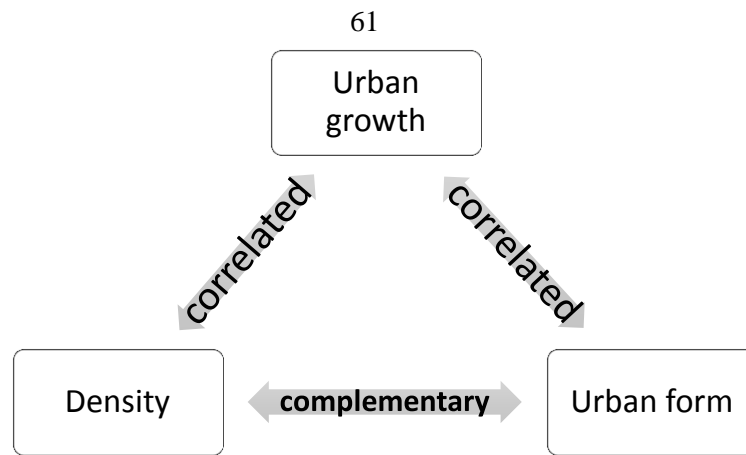


Figure 6: The conceptual relationship between the selected measures.

For a comprehensive understanding of urban form, a combination of several metrics should be employed. Density dimension on its own, for example, don't deliver a good indication of the geometric complexity or fragmentation of the urban form, which are considered sprawl characteristics. Two cities with similar areas and population will have the same density, but one may have its built area as a one major cluster, while the other as fragmented and scattered into many small clusters. A circular shaped city for example, can expand, in high density- non-sprawling development patterns, or expand in unbrokenly low-density sprawling patterns; one cannot analyse these characteristics by measuring shape of the urban form, thus, density gradients measure is important in this scenario (Angel et al., 2005). In this sense, it is important to use a set of measures for a complete assessment and a fuller understanding of sprawl.

Spatial geometry and density gradients are both necessary and complementary for each other, while urban growth analysis may correlate with the results of these two dimensions, for example, low density development is correlated with built-up growth rates outpaces population

growth rates. Similarly, scattered development correlate with outlying pattern of growth. However, low density growth doesn't necessarily indicate scattered growth.

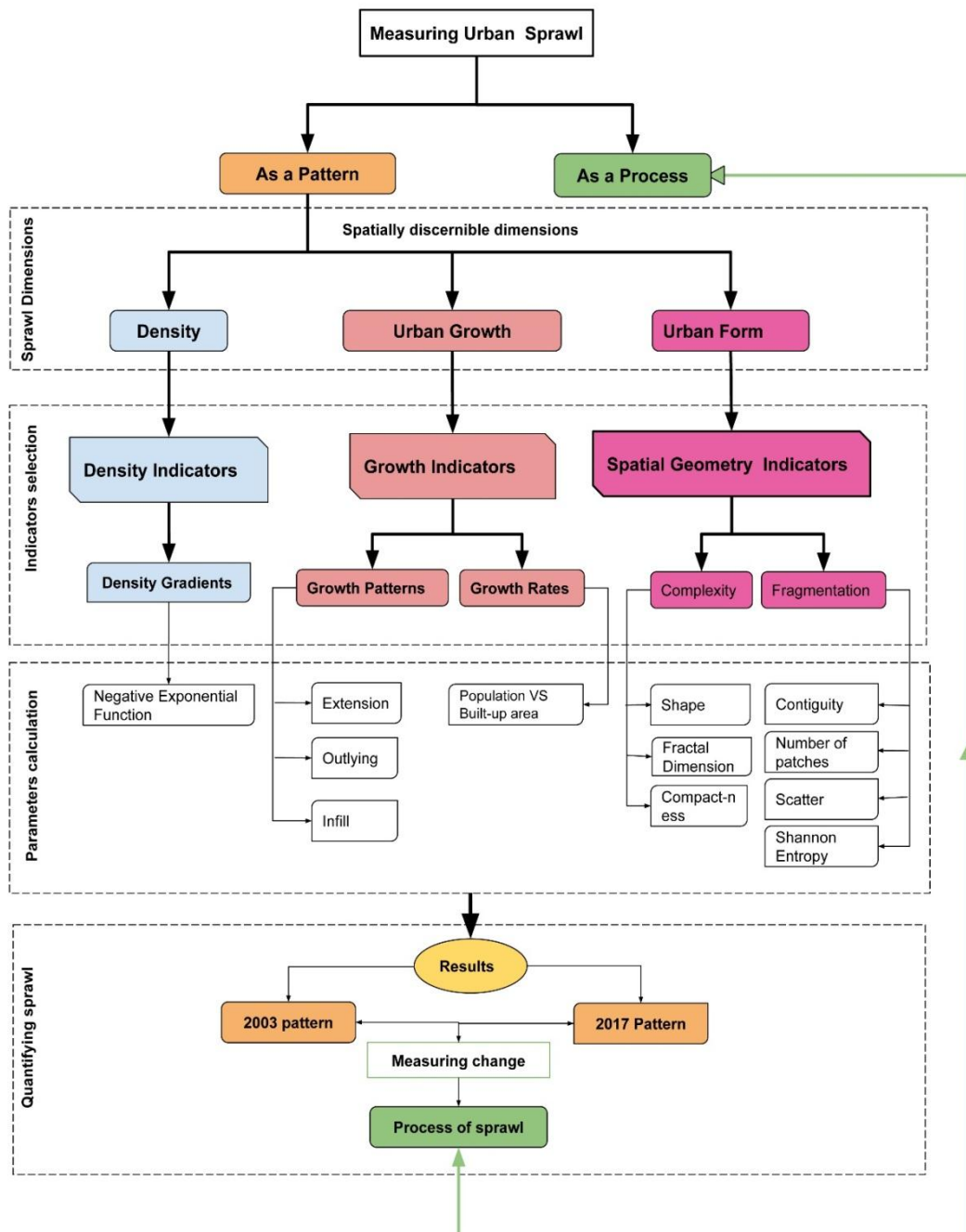


Figure 7: Conceptual framework and study methodology

The diagram illustrates the organization of analysis and the theory base of methodology. Urban sprawl is analyzed both as a pattern and a process. Pattern analysis was based on the three spatially discernible dimensions, namely as density, urban growth, and urban form. Each dimension was quantified through a set of parameters, then the change of the parameters value from 2003 to 2017 was calculated to reveal the process of sprawl.

3.2 Study Area

The West Bank is an elevated plateau with a small area of 5,655 km² (PCBS, 2018). It is administratively divided into 11 governorates, with 391 localities and 19 refugee camps (CEC, 2016) comprising the home of 2.8 million Palestinians (PCBS, 2017), and distributed in three main categories with regards to urbanization level, including urban population with a majority of 73.9% , rural population and camps as 16.7% and 9.4% respectively (PCBS, 2015). Major cities are considered the anchor of each governorate, where services and economic activities gathers and centralize.

The study area includes all major Palestinian cities in West Bank except for Jerusalem. Exclusion of Jerusalem was due to the politic

al disputation over the city, furthermore, the planning systems are affiliated with Israeli government urban strategies, aimed at encouraging the Israeli presence in the city and creating discontinuity among Palestinian settlements (Chiodelli, 2012).

Refugee camps were also excluded from the analysis. Refugee camps are informal settlement established after 1948 Israeli-Palestinian war, to accommodate Palestinian refugees. They are distributed among Palestinian cities in a temporary status, as refugees have the “right of return” to their homelands (United Nations General Assembly Resolution 194). Refugee camps has a very high density- clustered pattern, very small and adjacent residential units, with a harsh living environment. They are often confined form all edges, as a result, their expansion is very limited. For this reason, they were excluded from the analysis as they may skew the results.

Urban growth and sprawl studies in most cases concentrate on big cities and metropolis. Thus, this study will examine and compare sprawl for the **capital cities and their connected urban fringes**. Rural areas were not examined for their sprawl because (1) the comparative nature of this analysis concentrates on big cities with large population numbers in which growth could be significant, (2) urban areas and rural areas have different morphological and functional compositions. Urban areas have active commercial centers, infrastructure and services, and different jobs opportunities which are all considered significant drivers for development; whereas rural areas don't necessarily meet these criteria, and (3) the large number of rural communities (more than 430 in total, in 2017 (PCBS, 2017)) , in which the analysis would be time consuming. Further studies concerning growth and sprawl in rural areas could be subjected for future research.



Figure 8: Allocating the study area

3.3 Data and Methods

3.3.1 Data resources

To meet the objectives of this study, several data sources were approached. Main data needed for the empirical analysis were gathered from various resources including Palestinian Bureau of Statistics (PCBS), the Ministry of Local Government (MOLG), and urban and regional planning department in An-Najah National University (NNU). Secondary data for conceptualizing urban sprawl was obtained from relevant literature

resources including working papers, publications from peer reviewed journals, doctoral and master dissertations, and books.

3.3.2 Data Types

This research utilizes different sets of GIS based data, including shape files of buildings units, administrative boundaries, roads, cadastral maps, aerial images for 2003 and 2017; and population census data as the main inputs for the analysis. GIS databases for Palestinian cities were developed and digitized by ministry of local government based on different resources, and various thematic maps were created for all governorates. Demographic data are collected by Palestinian Central Bureau of Statistics (PCBS). These were last updated after the population, housing and establishments census, in 2017.

For the purpose of this study, 2003 building data and aerial images were obtained from the department of urban and regional planning in An-Najah national University. The selection of 2003 as the base year of the analysis was due to data unavailability before 2003. Other shape files including buildings of 2017 were retrieved from the ministry of local government website (GeoMOLG) and they are freely available for public access. GIS data used for the analysis are summarized in the table below:

Table 7: Types of GIS data sets used for the analysis

Dataset	description	Data mode	Type of feature	Source
2003 buildings	polygon	Vector	Summarized by area	NNU -Department of urban and regional planning student work
2017 buildings	polygon	Vector	Summarized by area	Ministry of local government
Administrative boundaries	polygon	Vector	continuous	GeoMOLG
2017 Land use map	area	vector	continuous	GeoMOLG
Roads	Polyline	Vector	Continuous	GeoMOLG
2003 aerial Image	Image	Raster	Continuous	Department of urban and regional planning NNU
2017 aerial Image	Image	Raster	Continuous	GeoMOLG
Contour	Poly lines each 5 m	vector	Discrete	GeoMOLG

3.3.3 Data limitations

The complexity of a dynamic phenomenon such as urban sprawl could be understood and approached through the application of various techniques and measures, thus requiring different types of spatial, temporal, and census data for several years.

- One of the aims of this study is to analyse the process of sprawl, by measuring the change of the related parameters in two time periods. For a better understanding of this process, a wider span of time is favourable, in which more than two time points are analysed, which in this research was not attainable due to GIS historic data limitations.
- The main input data for the analysis comprises buildings shape files with basic attributes of location and area. Attributes related to building type (commercial, residential, industrial), year of construction, height, or

number of residents in which assists in calculating vertical density, for example, were not available.

- Aerial images earlier than 2003 were not available .
- GIS data of 2003 were challenging to work with, that is attributed to the relatively low-resolution of 2003 image at the buildings scale; besides, 2003 buildings shapefile lacked accuracy in terms of the precise placement, the inclusiveness of all urban areas under study, and the number of buildings, it was found that some urban areas were totally missing.

The absence of such data restricted the analysis to include some indicators and exclude others. This problem is common in developing countries, where much work is still needed in the field of data collection and digitizing in comparison to developed countries.

3.3.4 Data pre-processing

Before proceeding with the analysis, data shapefiles and satellite images were georeferenced using “*define projection*” tool in ArcMap10.1 thereby ensuring the spatial consistency of data, and make sure that all layers are projected to the same geographic coordinate system, given as “GCS_Palestine_1923”.

2003 buildings shape file, which is manually digitized by urban planning students, contained obvious missing data and alignment errors. Missing buildings were manually drawn to the data layer by checking it against the aerial image of 2003. The alignment problem of the two years

was adjusted by checking all sets of 2003 buildings against the 2017 building shape file. Finally, all sets of buildings data for both years were repaired using the “*Repair Geometry*” tool in order to inspect each feature for geometry problems.

3.3.5 Delineating the built-up areas boundary

The builtup area shape file for both years 2003 (T1) and 2017 (T2) was created from buildings shape file using “*Delineate Built-Up Areas*” tool, which delineate densely clustered arrangements of buildings on small-scale maps (ArcMap description box). The “roads” shape file was used to dictate the boundaries of the output builtup polygons, and the grouping distance considered for the delineation is set as “100meters”, which is - by trial and error- found to be the most suitable for the analysis- in such that it doesn’t over-bound the buildings or leave much gaps inside the consolidated builtup area. Smaller distances such as 50 meters resulted in ignoring many buildings from the boundary. The following chart illustrates the effect of different delineation distances on the size of the builtup area boundary.

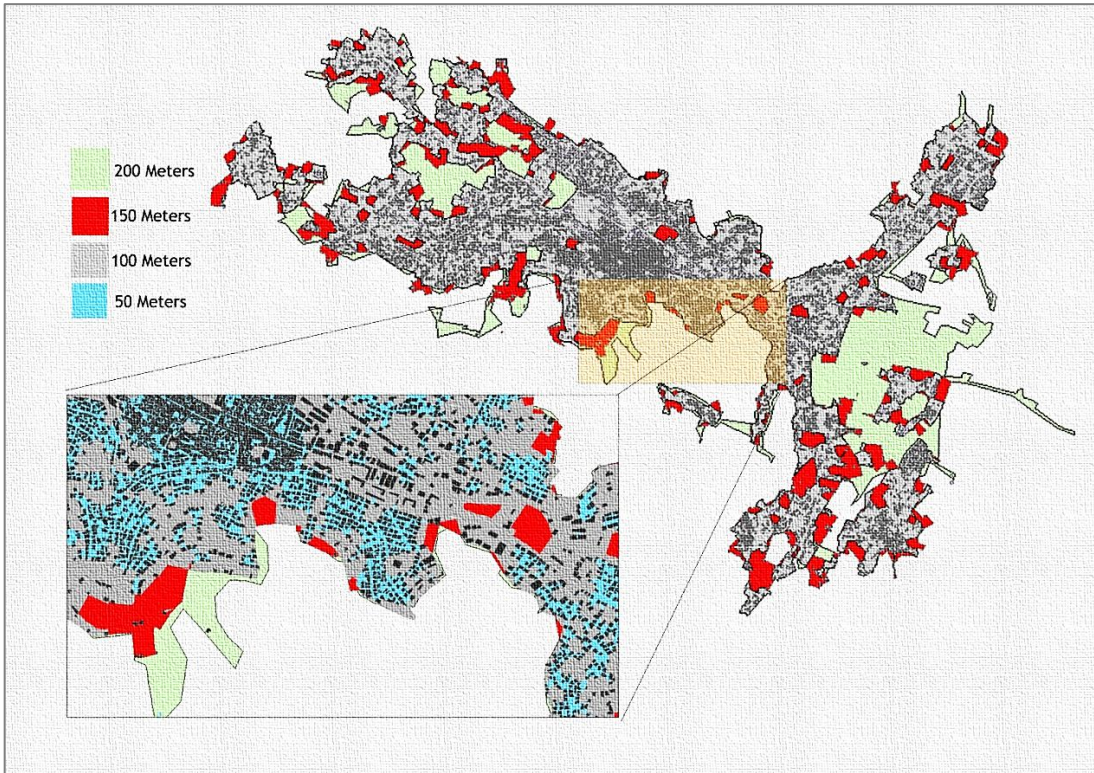


Figure 9: Different builtup area delineation distances for Nablus urban area.

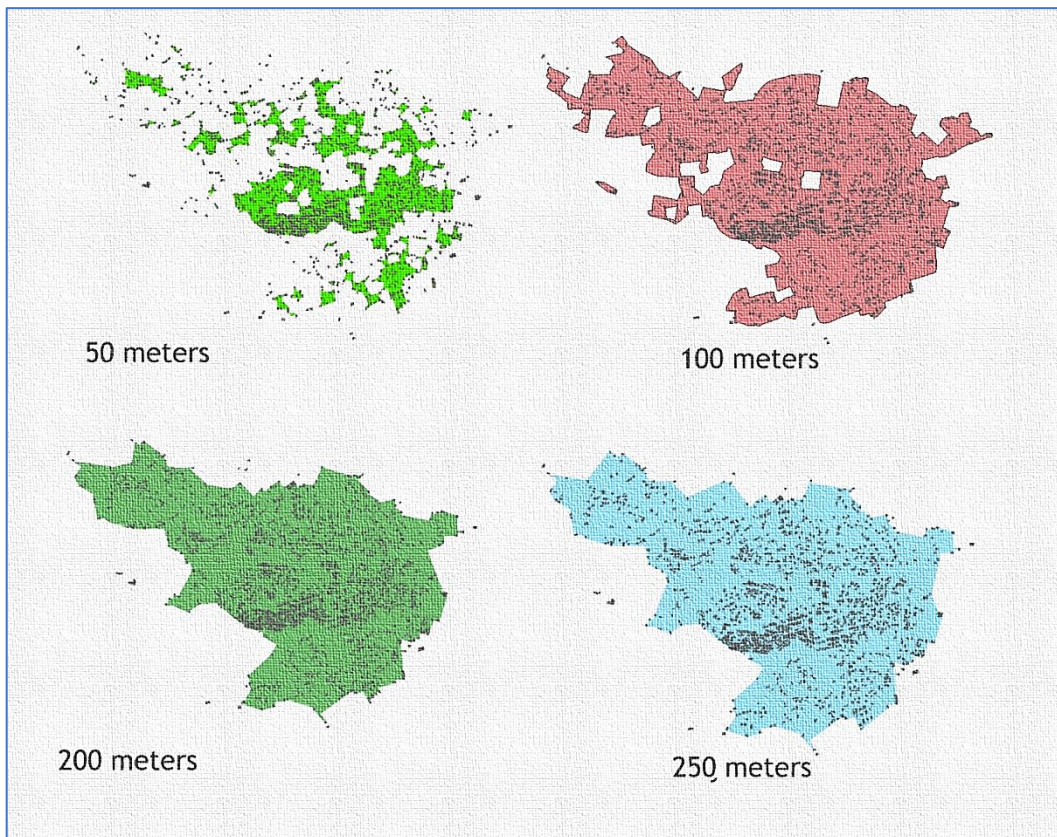


Figure 10: Different builtup area delineation distances for Salfit study area

3.3.6 Determination of the districts comprising the urban area - selecting the boundary

Rationale

The question about where the city ends, and the rural area begins cannot be clearly answered, modern cities and metropolis differ from old walled-medieval cities, in that they expanse beyond their limits and absorb surrounding urban fringes and suburbs (Angel et al., 2005).

Administrative boundaries of cities don't provide a proper edge for measuring sprawl. For effective and reliable study of sprawl, the boundary should be considered carefully. On the one hand, cities cannot be isolated from their surrounding urban fringes when measuring sprawl, because these suburbs are considered the epitome of sprawl. On the other hand, over-bounding of the study area will result in including more rural areas, which differ from urban areas in their land use - they usually have lower densities and larger farm land plots – thus skewing the results of some sprawl measures such as density, towards more sprawl (Galester, et al. 2001).

There are several approaches to determine the boundary. Each country defines its own administrative divisions or levels based on different political, geographic and social criteria. For their study of sprawl, Ewing et al., 2002 and Galester et al., 2001 used the “Metropolitan Statistical Area” (MSA) boundary, and the “Urban Area” (UA) defined by US Census Bureau respectively. Both boundaries had problems regarding the

efficiency of measuring sprawl (MSA for over-bounding and UA for under-bounding). The study of the world bank (Angel et al., 2005) delimited the boundary for a universal sample of large metropolitan areas using a different methodology. They created a 1 km buffer around the main builtup area, and whatever urban area intersected the buffer and its size exceeds 1 km² is taken with the analysis. Correspondingly, this research uses the same approach of the world bank study but with a smaller buffer distance, since Palestinian cities are smaller in size than the large metropolis of the world.

3.4 Analysis

This study included all the contiguous urban fringes that were totally connected to the main urban area, as they are the essence of sprawl. Determination of all the regions comprising the urban areas is done using the 2017 builtup area shape file, which shows all the districts that became connected with the main urban area.

Districts to be contained in the “consolidated urban area” were defined to be districts containing any part of which intersected a 0.5 km buffer around the main builtup area of the capital city, and the area of intersection was assumed to be larger than 1 km². This was done by creating a buffer of 500 meters distance using “*buffer*” tool in ArcMap, around the main builtup area of 2017, for each capital city. Cities of Qalqilya, Salfit, and Jenin didn’t have contiguous rural regions connected to them in 2017. Finally, the main built-up area of each capital city, and its

corresponding districts were merged using the “*merge tool*” and exported as a separate shape file with the name “the consolidated built up area”. This allowed for the calculations of the total built-up area of each corresponding city in both years. The following table summarizes each urban area with its accompanying districts included in the analysis:

Table 8: Definition of main study areas and their contiguous rural districts

Urban Area	Contiguous Rural Districts
Jenin	-
Tulkarem	Far'un, Kafa, Iktaba
Tubas	Ath Thaghrah
Nablus	Zawata, Beit Iba, Kafr Qallil, Rujeib, Beit Wazan
Qalqiliya	-
Jericho	'Ein ad Duyuk al Foqa
Salfit	-
Ramallah and Albeireh	Abu Qash, Surda, Beituniya
Bethlehem	Beit Sahur, Artas, Al Khader, Beit Jala, Khallet al Louza, Hindaza, Khallah Hamameh, Bir Onah, Ad Doha
Hebron	Beit Kahil, Taffuh, Al Baqa, Khallet Edar, Dura

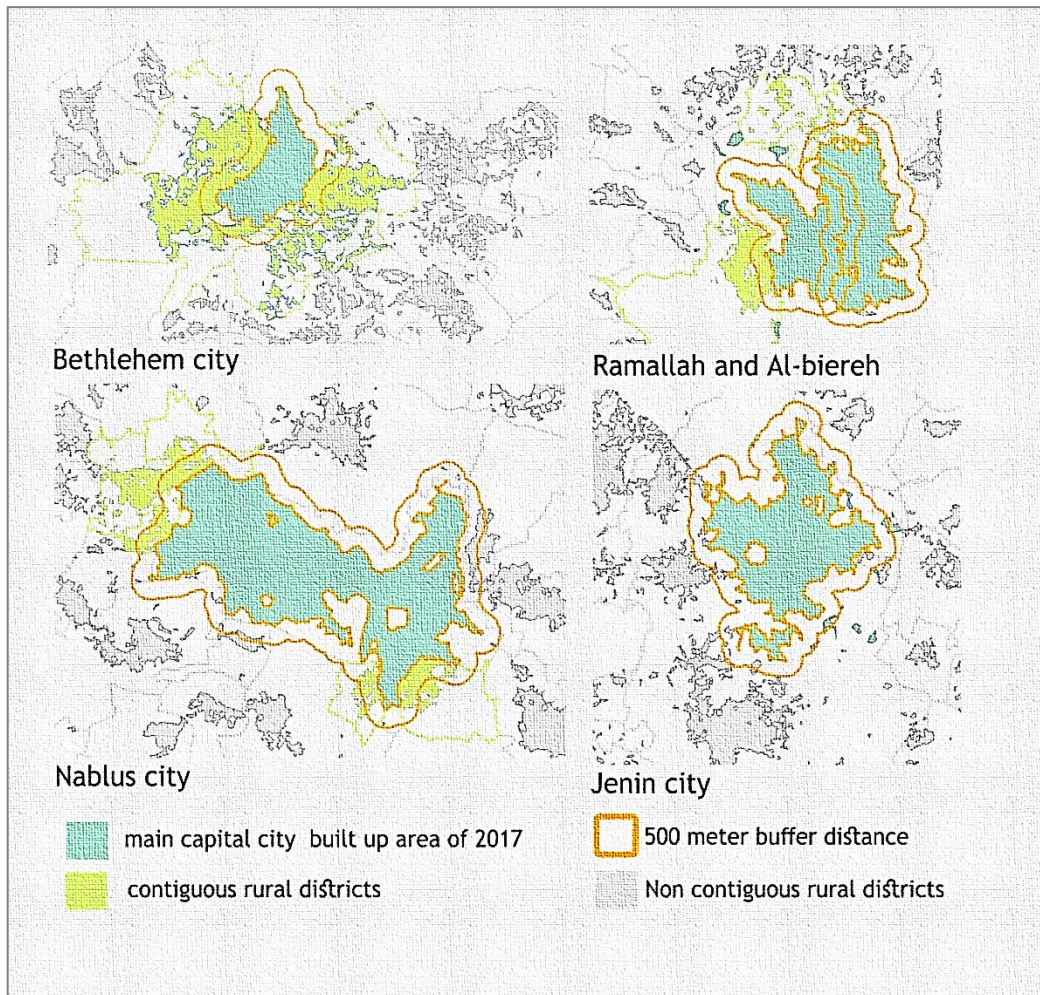


Figure 11: Determination of the districts comprising the urban area

3.4.1 Calculation of built-up area and population figures

Built-up area

Prior to calculating sprawl measures, built-up area and its rate of change should be determined. They are not on their own sprawl measures; however, they play a major role in the calculation of sprawl parameters. In this study, total built area and its expansion during the 14 years period was calculated using the geometric properties of built-up area polygons. A new field named “area” was added to the attribute table of the built-up area

shapefile, then the total built area for each city was calculated by summing all the built-up areas in the administrative districts that fully contained the city. Built-up areas for the cities of analysis are listed in the table below:

Table 9: Builtup area calculations for the study areas; 2003,2017

Urban Area	Built-up Area 2003 (km ²)	Built-up Area 2017 (km ²)	Increase in builtup area percentage
Jenin	6.83	11.51	69%
Tulkarem	8.87	14.62	65%
Nablus	13.24	23.63	78%
Tubas	2.49	4.89	96%
Qalqilya	3.57	4.95	39%
Salfit	2.30	3.07	33%
Ramallah and Albeireh	15.61	20.76	33%
Bethlehem	13.43	19.00	41%
Hebron	28.22	44.33	57%
Jericho	5.53	12.46	125%

Population

Population growth is considered as a significant driving force of urban growth in general, and urban sprawl in particular. In this study, population data was used to calculate *growth rates of population versus builtup area*. In the great majority of countries, population data is collected every decade in the national census. In Palestine, the national census has been conducted for three times, in the years of , 1997, 2007, and in 2017 (PCBS). The administrative districts provide the spatial framework for population counts in Palestine. Typically, people are counted in small census tracts , then population is aggregated to larger administrative districts.

This research used available population figures of 2007 and 2017 to predict 2003 population, which is four years earlier than the 2007 census. Population growth was assumed to be exponential, as cited in (Angel et al., 2005), and the annual growth rate (g) was calculated using the following equation :

$$P_{2017} = P_{2007} * (1+g)^{10}$$

Where P_{2017} is population in 2017 and P_{2007} is population in 2007. Given the annual growth rate (g), the population for 2003 - in which the satellite image was available- was calculated using the following equation, as in (Angel et al., 2005):

$$P_{2003} = P_{2007} * (1+g)^{(2003-2007)}$$

Then, the urban area population was calculated by adding all census population of all the districts comprising the urban area, for 2003 and 2017. Thus, the definition of the urban area population was inclusive in this study, as it's encompasses the non- urban population associated with the urban area. The following table illustrates the population counts for all urban areas under the analysis for the years of 2003 and 2017:

Table 10: Population counts for the main urban areas of the study; 2003,2017

Urban Area	Population 2003	Population 2017	Population Percentage change	Annual Growth Rate (%)
Jenin	34753	49908	44%	2.62%
Tulkarem	51750	72489	40%	2.44%
Tubas	14118	21431	52%	3.03%
Nablus	125060	173827	39%	2.38%
Qalqiliya	37676	51683	37%	2.28%
Jericho	17881	21792	22%	1.42%
Salfit	7949	10911	37%	2.29%
Ramallah and Albeireh	77399	115122	49%	2.88%
Bethlehem	73,132	97,012	33%	2.07%
Hebron	188,688	269,452	43%	2.58%

Population statistics of the urban areas for 2003, 2017

3.4.2 Acquiring elevation and deriving slope

One final step before calculating sprawl measures, is to derive slope. For the calculation of “compactness”, a shape index used in this analysis, the buildable area within the city has to be identified. Steep topographic slopes are considered as constrains and barriers to development. The buildable area of the city according to (De Roo, Gerd and Donald Miller, 2000) as cited in (Angel et al., 2005) is defined from a physical point of view as ‘the sum of all the areas within the circle that had slopes less than the maximum slope within the built-up area’. The maximum slope is defined in such that ‘99 percent of the built-up area had a less steep slope than the maximum slope (Angel et al., 2005). This study has accounted for the physical constrains of development and hasn’t accounted for political constrains.

Slope maps were produced using topographic maps retrieved from the GeoMOLG website for all urban areas. Topographic maps usually portray elevations as a set of contours of equal elevation , in our case, each 5 meters . In order to obtain slope maps “Topo to Raster” tool was used to create a raster surface from topography lines. This raster was used to create the slope map using “*Slope*” tool which Identifies the slope in gradient, or degrees from each cell of a raster surface.

It was found that 99 percent of the builtup area is less steep than 25 degrees slope, thus, the maximum slope was identified as 25 degrees, which is consistent with MOLG criteria .Based on this , slope map was reclassified into two classes including slopes higher than 25 degrees and slopes lower than 25 degrees. The final step was to convert the classified raster map to vector polygon map using “*Raster to polygon*” tool, in order to obtain the non-buildable areas, by erasing polygons of slopes lower than 25 degrees. The following charts illustrates the process of obtaining the non-buildable areas from slope.

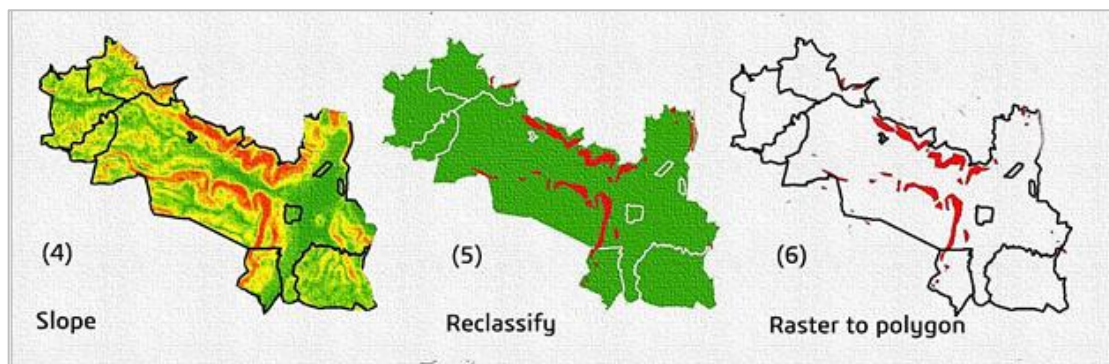


Figure 12: Acquiring elevation and deriving slope (Nablus area)

3.5 Calculations of Sprawl Measures

3.5.1 Density

Density is universally considered as the most essential component of urban sprawl; besides, quantification of sprawl patterns has traditionally been based on the notion of density. However, it's important to note that density is not the only measure of sprawl (Torrens and Alberti, 2000; Galester et al., 2001; Pieser, 1989; Lopez & Hynes, 2003; Fulton et al., 2001). **Density is defined as the ratio between the amount of a certain urban activity and the area on which it exists. Sprawl is defined as a condition in which a certain type of density is relatively low or decreases over time** (Frenkel et al., 2016). Sprawl usually occupies lower-than-average densities of urbanization. There are **different types of densities** related to urban activities such as population density, housing units per unit area, or employment density (Torrens and Alberti, 2000). According to Burchell et al., 1998, density is a **relative value**, where sprawl is not a development less than the maximum density, rather, it refers to development that has **relative low density**. In this study , density is considered as the most important sprawl measure. For the calculation of this dimension , density gradient parameter and its change in time was considered.

It's true that density constitutes the most important sprawl measure, however, many scholars carefully consider it for measuring sprawl due to some limitations . First, density fails to explain the urban form, which is also an important dimension of sprawl. For example, two cities with the same population counts and the same area, but with different shapes ,will have the same density value. The second factor is the unreliability of using the municipal boundaries in density calculations. Administrative boundaries can be way larger, or way smaller than the actual built-up area of a city; thus, using these boundaries don't reflect a precise measure of density. It can be concluded that density on its own is not a comprehensive measure. Still, these limitations can be compensated by using a combination of sprawl measures or (multidimensional sprawl index) such as shape indices to explain the urban form.

A. Density Gradients

Rationale

Density gradient is one of the most common approaches used to quantify density and analyse urban form (Torrens and Alberti, 2000; Ottensmann, 2018; Knaap et al., 2005). This approach has found its origins in the economic theory. According to economists, concentric rings around the CBD represent the rent gradient, that peak in the center, and decline exponentially along the gradient, known as the monocentric model (Knaap et al., 2005). This approach assumes the strong role of the CBD in the urban form, suggesting a monocentric city in which population,

employment and other activities are concentrated in the main urban core, and the density tends to attenuate as a negative exponential function from that core (Ottensmann, 2018). This model also predicts the activity density at any distance from the center to be a function of the central density, through a set of parameters fitted to the density gradient (Torrens and Alberti, 2000).

Density gradients are useful indices for characterizing sprawl, they give an indication of the degree of nuclearity_ the extent to which the urban area has a mononuclear development pattern, as opposed to a poly-nuclear development pattern, and allow for the comparisons of the relative degree of sprawl among different cities in a multiple time points, thus allowing for the evaluation of the process of sprawl. A city with a smaller density gradient can be relatively more sprawling than a city with larger density gradient. (Torrens and Alberti, 2000) From this perspective, Urban sprawl represents a decline, or “flattening” of the density gradient curve over a specific period (Knaap et al., 2005). A flatter density curve indicates a sprawling trend or pattern in which the role of the urban center becomes less significant over time, it may also indicate a decentralization process, and the possibility of the emergence of new secondary centers competing the main center. a fully flat trend of data reflects the absence of structure in the urban form and thus a high degree of sprawl (knaap et al.,2005).

Several models have been developed to characterize densities, the main candidate for measuring sprawl is the negative exponential function (Torrens and Alberti, 2000), and can be given as:

$$D_{(x)} = D_0 \exp^{-\lambda x}$$

Where D_x is the density of activity at a distance x from the main core (population, housing, employment, etc..), D_0 is the density in the urban center (central density), λ is elasticity or the density decay parameter, and defined as the percentage change in density for a small change in distance from the main centre, or in our case, known as the “density gradient” of sprawl. As you move outward from the center and in any direction, density decays at a rate of λ . A fall in λ represents an increase in sprawl. This allows us to compare density attenuation and the relative degree of sprawl between different cities and different time points. (Torrens and Alberti, 2000; Knaap et al., 2005; Ottensmann, 2018). In analysis, density gradient parameters are obtained by fitting the negative exponential trendline to the direct observations of density values in thin concentric rings around the center.

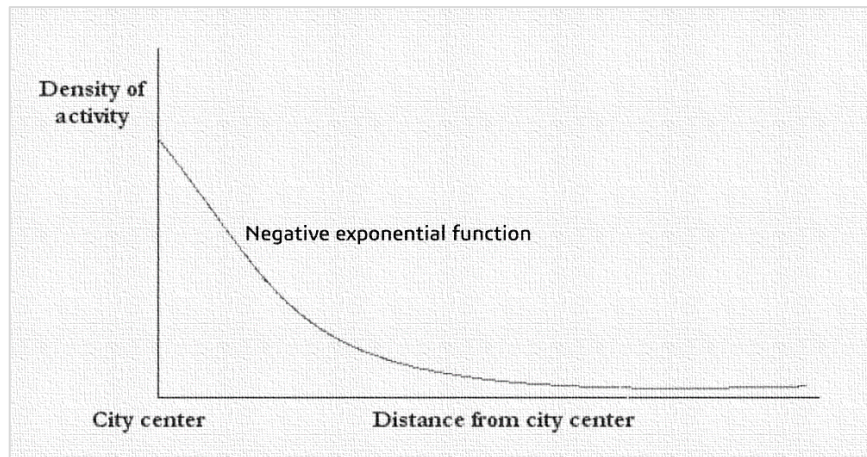


Figure 13: The shape of density gradient function, (Source: Torrens and Alberti 2000)

Numerous studies have shown the tendency of density gradients to fall over time (Ottensmann, 2016; Angel, 2012; Ewing et al., 2002; Clark, 1951; Mills, 1972; Torrens and Alberti, 2000). It was also found that central densities are higher, and density gradients are steeper in old cities (McDonald, as cited in Knaap et al., 2005). Mills and Tan, 1980 declared that most urbanized areas in developed countries exhibit a continuous flattening in their density gradients over time since 19th century. Bertaud and Renaud, 1997 examined density gradients trends around the world, it was found that central densities are higher in Asian cities, moderate in European cities, and the flatter curves and the lowest central densities were found in USA.

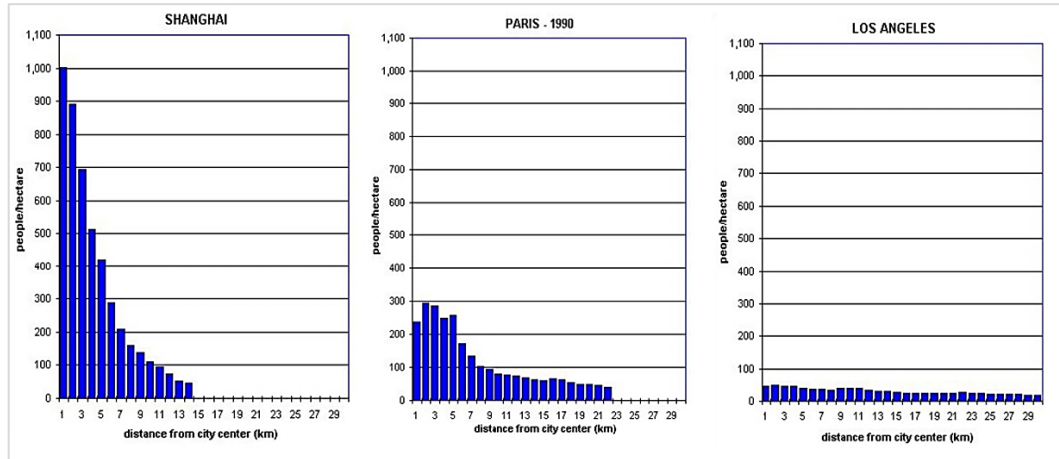


Figure 14: Density gradients for Shanghai, Paris, and Los Angeles (Source: Bertaud, 2001 as cited in Knaap et al., 2005)

Analysis

In this research, density gradients were calculated for the group of cities using the buildings unit's data. No distinction between residential and nonresidential type of buildings were made due to data limitation. Buildings unit's density was chosen over the commonly used population density, because buildings constitute a better representation of pattern as they're physically fixed, while population distribution changes (Galester et al., 2001; Ottensmann, 2016). The density decay parameter (l) was obtained for each city in both 2003 and 2017. The determination of sprawl was made by looking at the change in (l) value. If the value dropped from 2003 to 2017, then sprawl has relatively increased. Steps for calculating density included the following:

- **Definition of centers**

The central point for each urban area was manually allocated by choosing a reasonable location at the middle of the old town of each city. The reason for not using mean or median centers was the incorporation of the contiguous rural areas as a part of the main urban area in the analysis, which will result in a displacement of the actual center. The centers shape file then was exported as a point features shape file.

- **Creating buffers**

A series of thin concentric buffer rings were created around each center using “*multiple ring buffer*” tool at a specified distance of 200 meters for each ring. The reason for choosing a small distance is to create a smooth curve of density and to obtain a more precise results. The buffers then were intersected with the urban area boundaries to eliminate any empty ring using “Intersect tool” for both years. A “*spatial join*” was made to attach the created buffers with their governorate’s names based on their spatial locations, in order to recognize them in the coming steps.

- **Kernel density estimation**

Density of buildings units were calculated using kernel density approach. This method looks at the continuous variations of the activity density, and the patterns of sprawl, over the entire spatial range of the urban area. Theoretically, a kernel density estimator forms a moving window or “tile” overlaid on several “fine resolution grids” that has density

values associated with them. The window looks at the group of neighboring cells falls within it; the values of the cells are then summed and averaged, and the mean value is assigned to the central cell of the tile (Torrens and Alberti, 2000).

This approach is a better alternative over the traditional methods of density calculation for sprawl. It can overcome the problems associated with zonal density calculations, including the modifiable areal unit problem (MAUP), and filling in the blanks left by zonal geography. The exclusiveness of the method conducted by this study comes from combining the density gradient approach and the kernel density approach to estimate density at different distances from the center. (Torrens and Alberti, 2000).

This was done by first converting all buildings polygons to points data for both years using the “Feature To Point” tool, which creates a feature class containing points data from the representative locations of input features. Kernel density was then applied on the set of points for both years using “Kernel Density” spatial analysis tool within GIS, with a fine resolution cell size of 10, and a unit area of squared kilometers.

- **Zonal statistics**

The final step in this measure was to collect density values on zonal basis for each urban area. This was done using “Zonal Statistics As Table” tool. This tool tabulates the values of a raster within the zones of another dataset and reports the results to a table (GIS help box), which in our case,

were the kernel density raster surface and the buffer zones. the mean value of the estimated density in each buffer zone was selected for the analysis.

Then finally, using “*Table to dBASE*” tool, all tables were converted to Excel format, where all values of distances and their associated density values were plotted and graphed for each urban area in 2003 and 2017, for the final calculations of density gradient parameters.

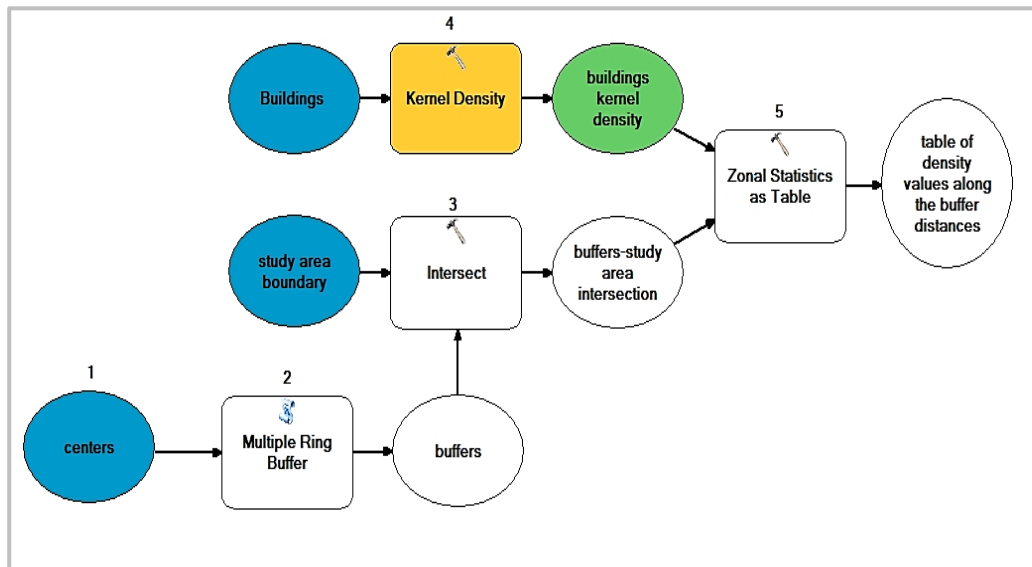


Figure 15 : Model of calculating Density Gradients using GIS

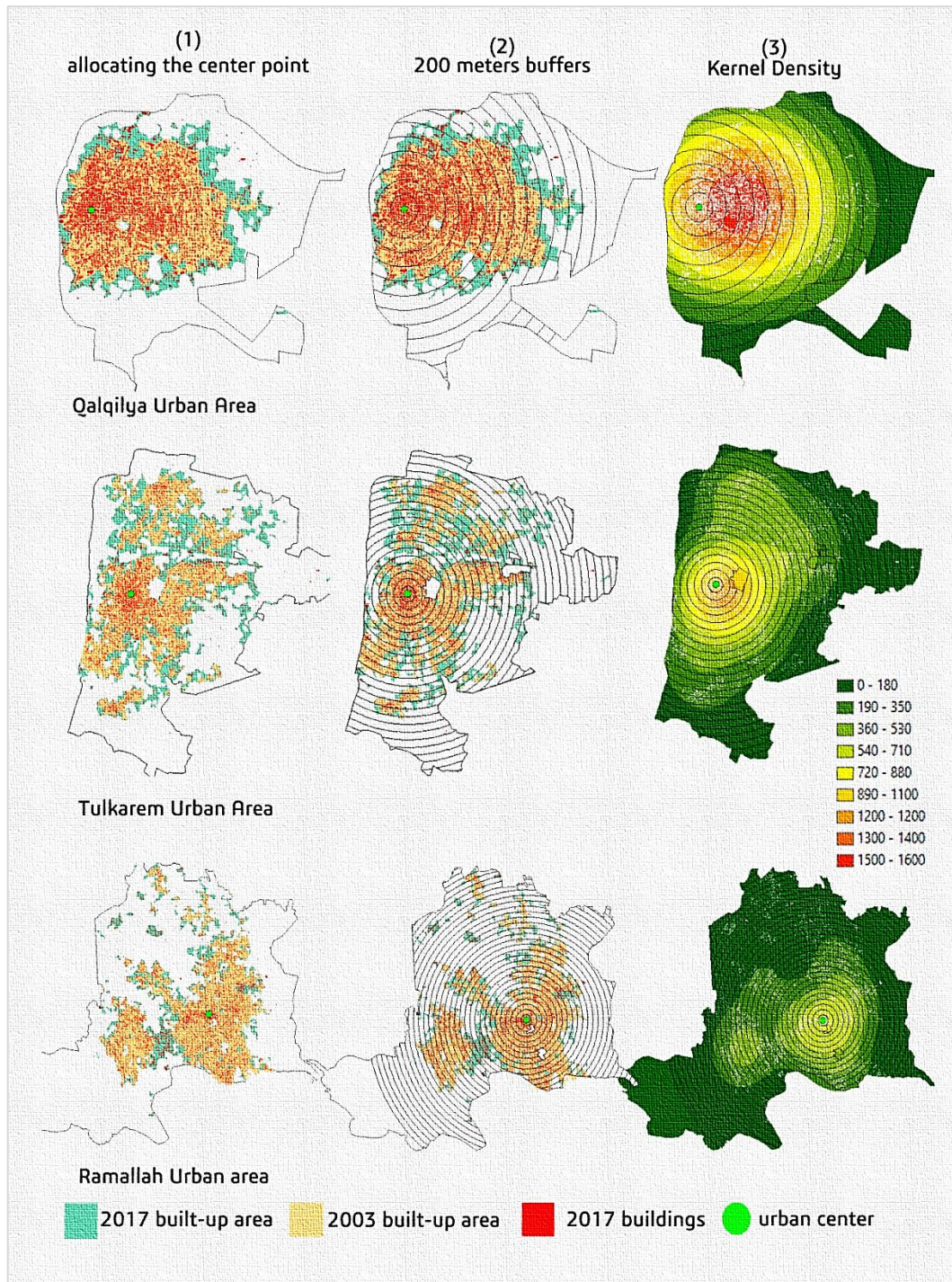


Figure 16 : Illustration of density gradients calculation method (Qalqilya, Tulkarem, and Ramallah area)

3.5.2 Urban growth Indicators

A. Growth rates of population versus growth rates of built-up area

Rationale

Sprawl is usually referred to as excessive urban growth. The main cause of urban expansion is population growth, as people demand a more space for living. Many sprawl measures reflect the relation between built-up area growth rate and population growth rate. A black and white hypothetical approach for determination of sprawl is: when spatial growth exceeds population growth, it's an indication of sprawl (Burgess and Thomas, 1997; Glaeser and Kahn, 2003; Lopez and Hynes, 2003; Bhatta, 2010; Sudhira and Ramchandra, 2004; Ewing et al., 2002; Burgess and Thomas, 1997; Fulton et al., 2001; Barnes et al., 2001; Gordon and Richardson, 1997)

Analysis

For this purpose, growth rates of built-up area and population for the 10 urban areas in west bank were brought into relation, using the previously calculated population figures and built-up areas. A sprawl index is defined as the ratio of the increase in built-up areas to the increase in population in that area between 2003 and 2017. A quotient higher than 1 implies urban sprawl (Hadly, 2000, Weitz, 1999 as cited in Frenkel et al., 2008)

$$\text{Sprawl index} = \Delta \text{Built-up} / \Delta \text{population}$$

B. Growth patterns

Rationale

This measure aims at investigating the patterns and the locations of new growth areas between 2003 and 2017 for all urban areas under analysis. This method was introduced by Wilson et al. 2003, as a way of measuring sprawl, in which the analyst can decide for himself for what to consider as sprawl or not. Wilson defines three types of urban growth: The infill pattern, the expansion pattern, and the outlying patterns, with outlying is further subdivided to three categories: isolated, linear, and clustered. In this research , we will investigate the main three types of growth, with no distinction among the outlying patterns types. The relation to existing developed areas is important for determining the type of urban growth occurring at the urban area.

In fill growth is defined as “all new development between two time points within vacant and open space in already existing built-up area” (Angel et al., 2012). Expansion growth is defined as: “all the new development adjacent to the periphery of an existing urban area extending its foot print in outward direction”. Outlying growth is characterised by new construction that occurs between two time periods, entirely outside the exterior open space of the earlier period (Angel et al., 2012, Wilson et al., 2003).

The percentages of each type of growth will be calculated and compared to determine which type is occurring the most, and to assess if the urban area is going towards sprawling or not. Infill growth is not considered as sprawl; by contrast, outlying patterns are considered as sprawling patterns; whereas extension growth can be considered as sprawling if exhibits low density patterns. Extension growth percentage can be also related to the previously calculated index of “growth rates of builtup area and population” to support the decision of considering it as sprawl or not.

Analysis

The spatial patterns can be visually discerned by mapping growth in time. For the sake of precision, building units were used instead of built-up area, especially with the infill type of growth, which usually occupies small vacant spaces inside already builtup area. The source of error in buildings counts are very minor and is attributed to the missing data through the digitizing and reviewing processes or merging adjacent buildings in a single boundary. The 2003 built-up area boundary was used as the reference for determining the location of new buildings, and the total increase in buildings number was calculated for each urban area.

For the determination of the infill growth, the holes within 2003 urban boundary, in which the new infill development will take a place, were cleaned. Using the “*Minimum Bounding Geometry*”, a mask layer of the 2003 built-up area was created and used as a gap-filling layer, through a set

of spatial tools and steps within GIS, explained in detailed in figure (15). Using “*select by location*” tool, the counts of buildings inside the 2003 gap-free boundary for both years were obtained and used to calculate the percentage of new in-fill development, where:

Infill growth number = 2017 buildings counts inside 2003 boundary - 2003 buildings counts

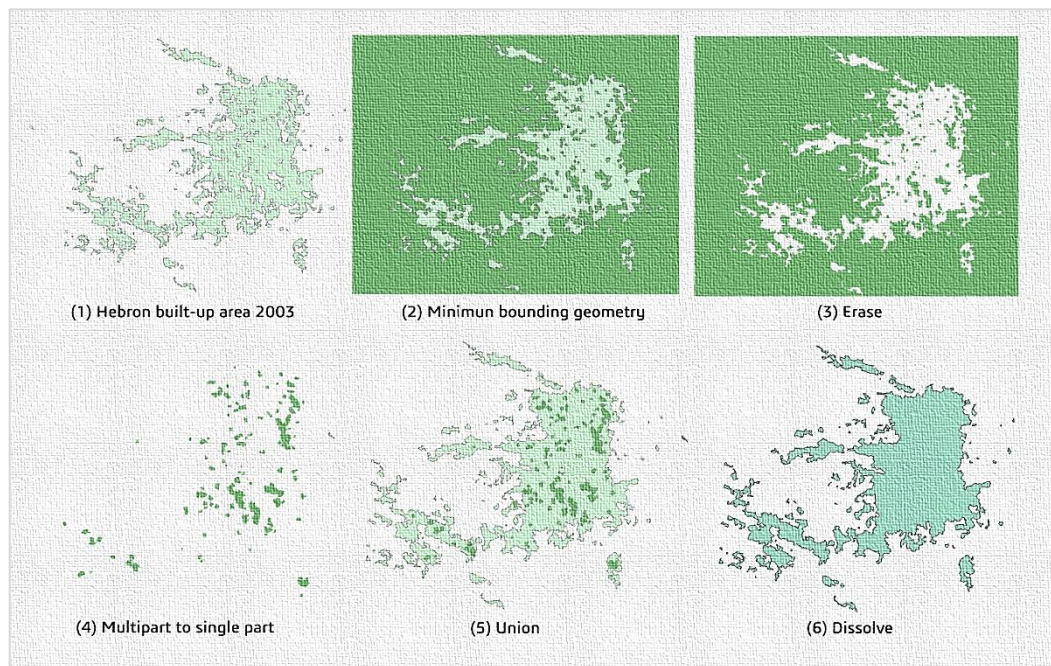


Figure 17: Illustration of in-fill growth extraction method (Hebron area)

The remaining 2017 buildings either takes the form of extension patterns or outlying patterns of growth. For locating them, built-up areas for both years were intersected using the “*Intersect*” tool. Using “*select by location*” tool, all 2017 builtup areas intersecting the source layer feature of 2003 were selected and exported as “the extension areas” shape file. Finally, buildings of 2017 inside these extensions were counted using “*select by location*” tool again, but now for 2017 buildings contained in the

extension layer. The remaining buildings that were neither infill, nor extension, were counted as the outlying pattern of growth.

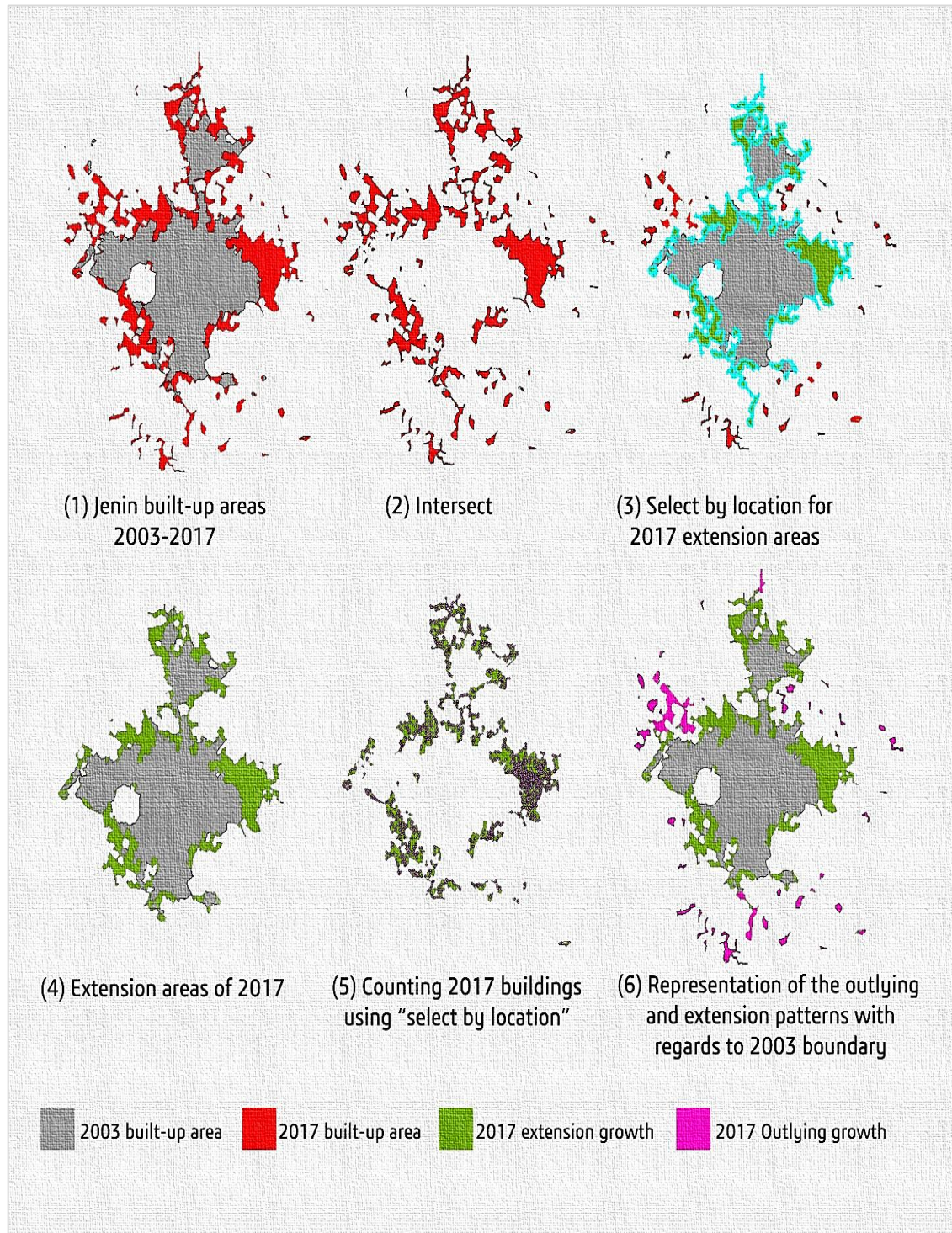


Figure 18: Illustration of extension growth extraction method (Jenin area).

3.5.3 Spatial geometry indicators-measuring the urban form

Rationale

Analysing the multi-dimensional aspects of sprawl requires using a combination of several metrics. Density dimension on its own, for example, don't deliver a good indication of the geometric complexity or fragmentation of the urban form, which are considered sprawl characteristics. Two cities with similar areas and population will have the same density, but one may have its built area as a one major cluster, while the other as fragmented and scattered into many small clusters. A circular shaped city for example, can expand, in high density- non-sprawling development patterns , or expand in unbrokenly low-density sprawling patterns; one cannot analyse these characteristics by measuring shape of the urban form, thus, density gradients measure is important in this scenario (Angel et al., 2005). In this sense, it is important to use a set of measures for a complete assessment and a fuller understanding of sprawl.

The spatial geometry dimension of urban sprawl comprises the largest group of sprawl measures, which are mainly adopted form ecological research and fractal geometry (Frenkel et al., 2008; Torrens and Alberti, 2000; Herold and Menz, 2001). According to Bhatta,2010, the spatial geometry of the urban form can be measured using spatial metrics .

Spatial metrics can be grouped in two categories, according to type of spatial characteristics evaluated: measures of composition, and measures of *configuration* (Frenkel et al., 2016). Measures of *composition* are

concerned with the heterogeneity level of built-up area with regard to its mix of land uses; whereas measures of configuration are concerned with the geometric properties of the urban form (Bhatta, 2010; Knaap et al., 2005). Statistically, many of these metrics are correlated; there are few basic measures that can be obtained from patches (Sudhira and Ramachandra, 2004).

Selected metrics

In this study, spatial Geometry of urban form was analysed using spatial metrics at two levels, the landscape level and the urban patch level. Since we make no distinction between urban land use types, these metrics would apply to any kind of builtup land (this is the approach of Sudhira and Ramachandra, 2004; Gar on Yeh et al., 2001; Li, 2012; Angel et al., 2005 and others). All metrics were examined spatially considering only the urban and non-urban uses, and temporally by measuring the change in their values between 2003 and 2017, for the ten urban areas under analysis.

The selected metrics can be classified based on the type of the characteristics being assessed to two types, measures of complexity, and measures of fragmentation. An urban area is considered sprawling as long as its geometric configuration is irregular, scattered, and fragmented (Frenkel et al., 2016).

- **Measures of complexity**

In terms of sprawl, Irregular and complex forms are considered sprawling, in comparison to a circular or simpler form. A city can be built as one full cluster, but its form can be linear, or star shaped. One cannot evaluate these aspects unless by using shape metrics. Geometric complexity is measured through different mathematical relations of the area and perimeter of the urban patch. For this research, the selected metrics of complexity are: Fractal dimension, shape index, and compactness index.

- **Measures of fragmentation**

Several sprawl definitions deal with discontinuity of builtup patches as a typical sprawl feature. The term Fragmentation is used as an umbrella term to describe similar concepts such as Dispersion, subdivision, isolation, scattering, discontinuity. These are all amounts of the same thing; tracts of developed lands separated from each other by open space and leading to a fragmented landscape (Fragstats; Torrens and Alberti, 2000). It is also important to look at the temporal changes in the scattered characteristics of builtup areas, as these areas become less scattered by infill development with time (Peiser 1989). Fragmentation metrics measures the degree of unbroken built area on the landscape level. For this research, selected metrics include: Contiguity index, scattering, number of patches, and Shannon entropy.

Table 11: Selected metrics of urban form and their description

	Metric	Description
Complexity Indices	Fractal dimension	Measure of shape complexity based on perimeter-area relationship. Simple forms like triangle, circle, and square are close to value of 1, complex forms are close to 2
	Shape Index	Measure shape complexity with regards to an optimum circle with the same area. Higher shape index values indicate more complex structure
	Compactness Index	Provides a measure of the overall patch elongation, or the extent to which the area fills its two-dimensional space. The greater the compactness, the more concentrated the urban form is, and the lower the sprawl.
Fragmentation Indices	Contiguity Index	A possible measure of the extent to which the city is monocentric rather than polycentric. It's given as the percentage of area comprising the largest patch in the urban area. The higher the value, the more monocentric the city is, and the lower the sprawl
	Number of patches (Patchiness)	A measure of discontinuity of urban patches. The greater the patchiness, the more fragmented the landscape is, and the higher the sprawl
	Scatter	As a measure of the degree of scattering of the built-up areas. Higher scatter values indicate higher sprawl.
	Shannon Entropy	Measures the degree of spatial concentration or dispersion of the geographic variable among zones of the urban area. values closer to 0 indicates maximum compaction of the variable, and values closer to log (n) indicates dispersed distributions of the variable.

Analysis

- **Complexity Indices:**

A. The Fractal Dimension

This metric measures the shape complexity based on perimeter-area relationship. The advantage of using this index is the availability of applying it on a variety of scales (Turner and Ruser, 1988). The formula for calculating this index as defined by (Torrens and Alberti, 2000) is given as the following:

$$D \approx 2 \frac{\log P}{\log A}$$

Where D is the fractal dimension of sprawl, P is the perimeter of the urban patch, and A is the two-dimensional area of the related patch. The value of D ranges between 1 and 2. Values closer to 1 reflect simpler Euclidean shapes with relatively low sprawl, such as circle and squares, whereas values closer to 2 indicates complex shapes with more space filling edges and higher amounts of sprawl, such as star, rectangle or linear.

The main consolidated built-up patch was considered for calculating this metric. Area and perimeter data were obtained from the table of attributes of builtup area polygons shape file in GIS, and the rest of calculations were conducted in Microsoft Excel.

B. Shape Index

This is another fractal dimension index that measure shape complexity, but with a standardization to a simple Euclidean shape. Geometries of different shapes have different shape indices. The round shape has the smallest index, followed by a square, rectangle, star, H-shaped, line shape has the highest index (Lo,C.P., 1980 as cited in Li, 2012). For this measure, the geometric form of the urban patch is compared to an optimum circle with the same area. (Knaap et al., 2005) The formula of the shape index is given as:

$$Shape = \frac{Pi}{min Pi}$$

Where P_i is the actual patch perimeter and $min P_i$ is the theoretical optimum perimeter of a circle with the same area. Perimeter and area data were obtained from GIS, and the calculating of the measure was completed in Microsoft Excel. Higher shape index values indicate more complex structure and higher amounts of sprawl.

C. Compactness Index

It is suggested that more circular and compact cities should have shorter travel distances (Angel et al., 2005). Compactness index is another shape assessment method that provides a measure of the overall patch elongation, or the extent to which the area resembles a circular disk (Fragstats, Angel et al., 2005). It is defined as the ration of the patch area and the area of the smallest circumscribing circle.

Compactness for this research was define as the ratio between the consolidated built up area within a circle , and the buildable area within that circle. In practise, some areas had very small distant urban clusters, which made the circle too large , so, for keeping the meaningful intuitive of this index, the circle was restricted to the main urban patches. The smalles circumscribing circle was drawl using “ *minimum bounding geometry*” tool in GIS (Angel et al., 2005).

The calculation of this metric accounts for the limitations imposed by steep slopes as well. Steep slopes areas intersecting the circumscribing circles were calculated , using the non-buildable areas shape file produced

in earlier , then the final index values and their change between 2003 and 2014 was obtained. Compactness is given as :

$$\text{Compactness} = \frac{\text{builtup area within a circle}}{\text{buildable area within the circle}}$$

The greater the compactness, the more concentrated the urban form is, the lower the sprawl.

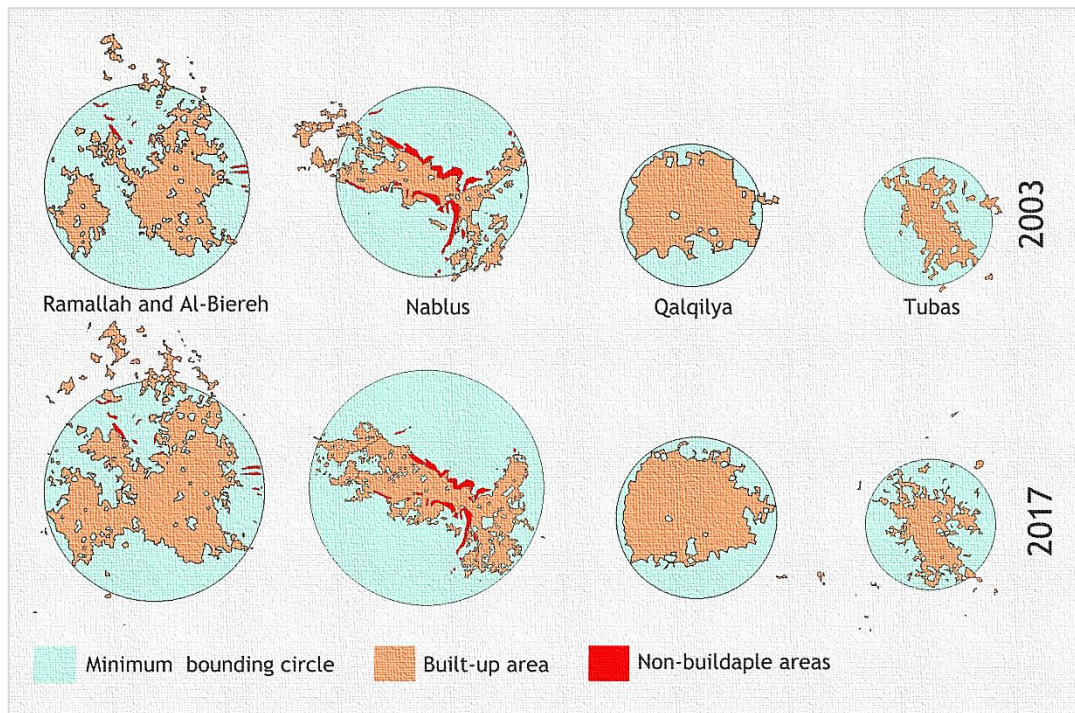


Figure 19: Calculation of compactness index

- **Fragmentation Indices:**

D. Number of Patches

This is a simple and straight forward quantification of the urban form. It doesn't contain any information about area or distribution of patches , rather, it is a measure of discontinuity of urban patches. This metric provides an indication on the number of new built-up patches created in

time (Herold et, al. 2002). The greater the patchiness, the more fragmented the landscape is, and the higher the sprawl. This measure was computed by calculating the number of polygons of builtup areas and their change in time for each city. If the number of patches decreased with time, this indicates a coalescence process of the urban patches.

E. Contiguity Index

This measure provides a summary measure of the urban spatial structure, by examining the distribution of clusters of the urban area. It is a possible measure of the extent to which the city is monocentric rather than polycentric. Contiguity is defined as the ratio between the urban area of the largest patch and the total built-up area of the city, or in other words, the percentage of area comprising the largest patch in the urban area (Angel et al., 2005) . another name used for this metric is (Largest Patch Index). This measure was calculated for both years using the following formula :

$$\mathbf{Contiguity} = \frac{\mathbf{Bm}}{\mathbf{Bs}}$$

Where Bm is the size of the main builtup area , defined as “the largest polygon or several contiguous polygons only separated by rivers”, and Bs , the sum of the areas of all polygons in the urban area (Angel et al., 2005). The higher the value of the contiguity, the more monocentric the city is, and the lower the sprawl. very low contiguity values indicate the absence of spatial structure, and high amounts of sprawl.

F. Scatter

This measure was obtained from Torrens and Alberti, 2000 as a measure of the degree of scattering of the builtup areas. This metric was calculated using the weighted centroids approach. If the absolute center of a geographic zone is the middle point of that zone, the weighted centroid is the amount of displacement of this center, towards the direction of activity in that zone (Torrens and Alberti, 2000). This parameter can be calculated according to the following equation introduced by (Suen, 1998):

$$S = \sum_{i=1}^n \frac{(H_i E_i)}{H}$$

Where: S is the level of scatter, H_i is the number of buildings inside the zone i , E_i is the Euclidean distance between the absolute center of a geographic zone i and the weighted mean center of the development in a larger zone, and H is the total number of buildings in the urban area.

For the calculation of this measure, a grid of 400 * 400-meter cell size was placed over the urban areas of 2003 and 2017 using the “*create fishnet*” tool in GIS. 400 meters was thought to be a suitable length of the grid unit according to the scale of analysis. These grid cells were considered as the geographic zones which contained the buildings units. Using “*intersect*” tool, each grid was constrained to the limits of built-up area of each city. Following to that, grids containing at least one building unit were identified using “*select by attribute*” tool, then empty grids were erased.

The absolute center of these zones was defined as the middle point of each square by using “Feature to point” tool , then exported as separate shape file. The built-up area of each year was considered as the larger zone of development. Weighted center of development is defined as the mean center of all the buildings in each urban area for each year and generated using the “*mean center*” tool in GIS. The number of buildings inside each square was obtained using “*tabulate intersection*” tool, which calculates the intersection between two feature classes and tabulate the counts of the intersecting features.

The Euclidian distance between the absolute center of each zone in the urban area and the mean center of the urban area was calculated using “*point distance*” tool, which report these distances in a table. The rest of calculations were completed in Excel, and the level of scatter was obtained for all urban areas in 2003 and 2017 .Higher scatter values indicates higher sprawl, whereas lower scatter values indicates lower sprawl, and more compact forms.

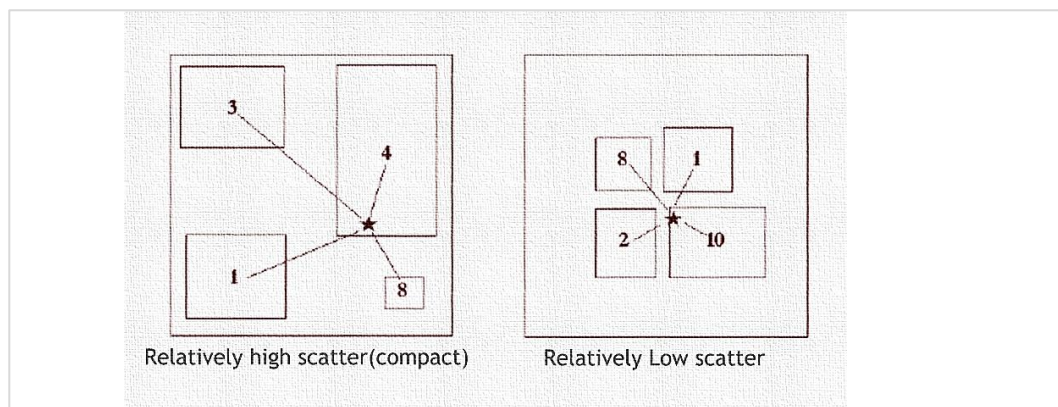


Figure 20: Scatter index (Source: Torrens and Alberty, 2000)

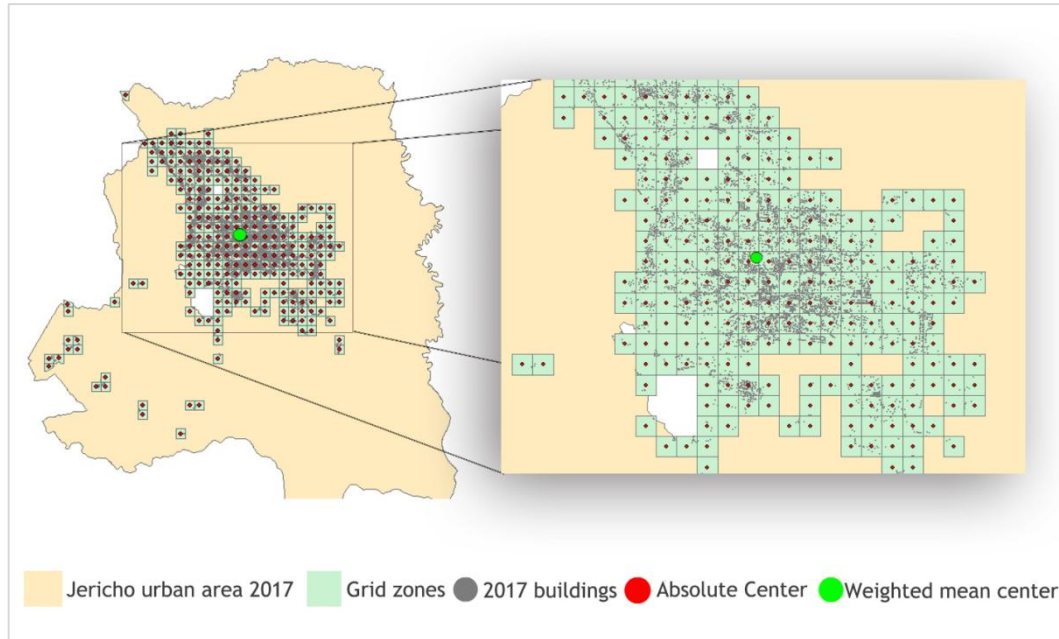


Figure 21: Calculation of scatter index

G. Shannon Entropy

The final fragmentation measure considered for this analysis is Shannon entropy. Shannon entropy is the most widely used sprawl measuring technique (Yeh and Li 2001; Sudhira et al. 2004; Bhatta, 2010). It measures the degree of spatial concentration or dispersion of the geographic variable among zones of the urban area. Entropy is given as :

$$E = \sum_i^n P DEN_i * \log \left(\frac{1}{P DEN_i} \right) / \log n$$

Where

$$P DEN_i = DEN_i / \sum_i^n P DEN_i$$

Where $PDEN_i$ is the density (proportion) of the variable in the zone i , and n is the total number of zones. The value of entropy ranges from 0 to $\log(n)$, where values closer to 0 indicates maximum compaction of the variable, and values closer to $\log(n)$ indicates dispersed distributions of the variable among the geographic zones (Bhatta, 2010; Sudhira and Ramachandra, 2004; Yeh and Li, 2001). Dividing the value of entropy by $\log(n)$ results in the relative entropy values, ranging from 0 to 1, and the value of 0.5 is the threshold of the entropy (Thomas, 1981). Since the entropy is used to study the distributions of the geographic phenomenon, the change in its values between two different time points can be used to identify whether land development is going towards a more dispersed patterns or not, or the process of sprawl (Yeh and Li, 2001; Bhatta et al. 2010).

The methods of generating the geographic zones, from which the data will be obtained, are varied and different in literature, some used the concentric circular buffer zones around the center, or the main roads; others used a squared concentric buffer zones, while others used quadrants to compare the entropy values between the parts of the same city. Thomas, 1981 and Yeh and Li, 2001, indicate that relative entropy method is favourable on traditional spatial statistics for analysing distributions, since it is less sensitive to size problems (MAUP).

For the calculation of entropy, two types of thematic layers are needed including the builtup area layer for both years, and the administrative boundary of the urban area. The pre-generated concentric buffer zones of

200 meters incremental radius around the main center were used as the geographic zones of calculation. Small radius incremental distances prevent losing information due to aggregation. These buffers were intersected with the urban area boundary using “*intersect*” tool in order to exclude areas outside the boundary from calculations.

The amount of builtup area inside each zone was obtained using the “*tabulate intersection*” tool , which calculates these values and report them in a table and exclude empty zones. the rest of calculations were completed in Microsoft Excel for obtaining the final entropy values for both years for all urban area. Following to that, the change in values was calculated to determine if cities are going towards dispersion or compaction.

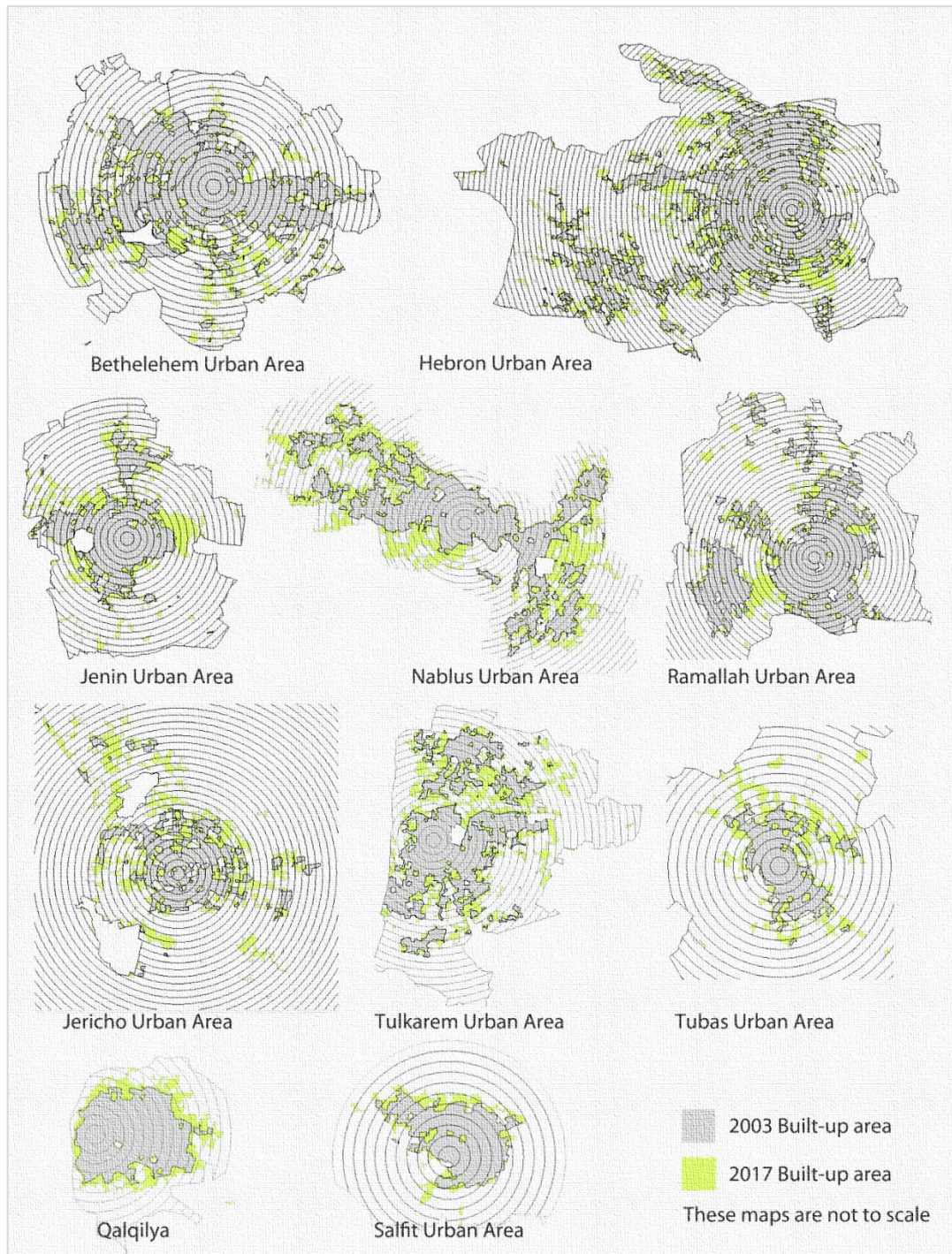


Figure 22: Calculation of Shannon entropy

Chapter Four

Results, Discussion and Interpretation

4.1 Sprawl Measures

4.1.1 Density dimension

A. Density Gradients

- **Results**

Table 12 : Density decay parameter values in 2003 and 2017

DISTRICT	Density Gradient (λ) 2003	Density Gradient (λ) 2017	Percent Change
Hebron	0.00047	0.00037	-22.30%
Nablus	0.00055	0.00045	-17.10%
Bethlehem	0.00062	0.00053	-14.70%
Ramallah	0.00066	0.00061	-7.60%
Qalqiliya	0.00097	0.00082	-15.10%
Jenin	0.00117	0.00093	-20.10%
Jericho	0.0011	0.00096	-13.10%
Tulkarem	0.00131	0.00099	-24.40%
Salfit	0.00133	0.00123	-8.10%
Tubas	0.00201	0.00163	-18.60%

- **Discussion**

Density gradients give an indication of the **degree of nuclearity**_ the extent to which the urban area has a mononuclear development pattern, as opposed to a poly-nuclear development pattern, and allow for the comparisons of the relative degree of sprawl among different cities in a multiple time points, thus allowing for the evaluation of the process of sprawl. **Urban sprawl represents a decline, or “flattening” of the density gradient curve over a specific period** (Knaap et al, 2005).

A flatter density curve (or a smaller (λ) value) indicates a sprawling trend or pattern. It may also indicate a decentralization process; a fully flat gradient reflects the absence of structure in the urban form and thus a high degree of sprawl. The determination of sprawl was made by looking at the change in density decay parameter values. If the value has dropped from 2003 to 2017, then sprawl has relatively increased.

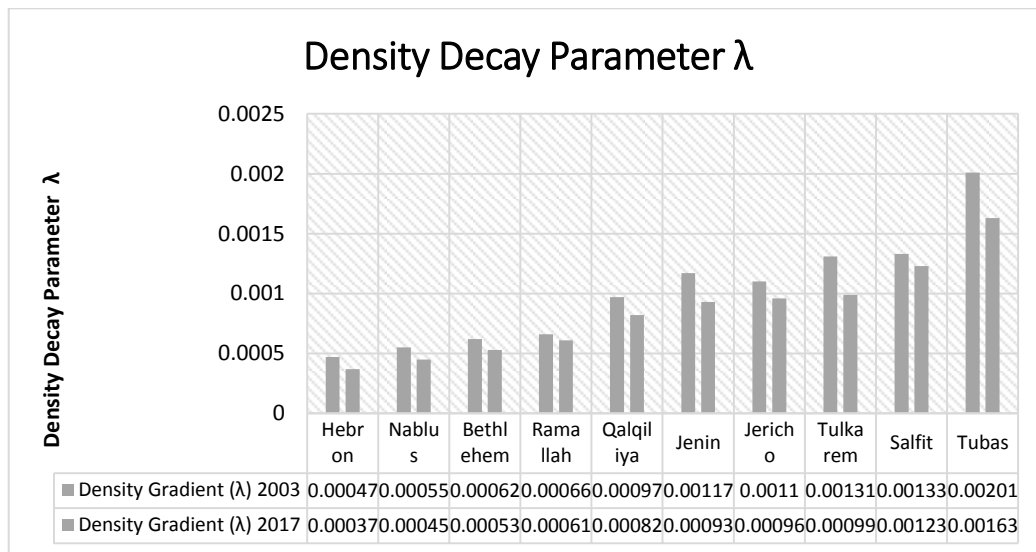


Figure 23: Density decay parameter values

The table and the chart above show a **falling tendency of density gradients over time**. λ value has dropped through the study period for all urban areas with different magnitudes, and the **density gradient curves became less steep** for all areas in 2017 indicating a sprawling trend dominating that period. The amount of decline for each urban area determines the degree of sprawling trend and allows for the comparison among all urban areas. Furthermore, **A city with a smaller density gradient can be relatively more sprawling than a city with larger density gradient**. (Torrens and Alberti, 2000); from this perspective, we

can compare urban areas for their density gradients value and the change in that value, to determine the most sprawling area.

The chart above illustrates the values of λ for all urban areas and sort them from the highest to the lowest. The city with the lowest λ value is Hebron. This means that Hebron is the least centralized urban area among others with a high degree of suburban sprawl. This can also be noticed from the map of Hebron, noticing that, from 2003 to 2017, the area has witnessed a suburban expansion into adjacent rural areas, leading to fusion of their builtup area boundaries. Nablus, Bethlehem, and Ramallah followed next indicating relatively high decentralization of their main built up areas into rural areas. The city with the highest λ value is Tubas, followed by Salfit and Tulkarem, all indicating relatively low amounts of suburban development and a more monocentric rather than polycentric structure.

The amount of change of density decay parameter is also compared between all urban areas allowing for the evaluation of the process of sprawl. The following chart sort the urban areas descending based on the change in density gradients. The most declining gradient from 2003 to 2017 was recorded in Tulkarem city, followed by Hebron, and Jenin. These three cities have changed the most in their structure between 2003 to 2017. A relatively low amounts of change was recorded in Salfit and Ramallah.

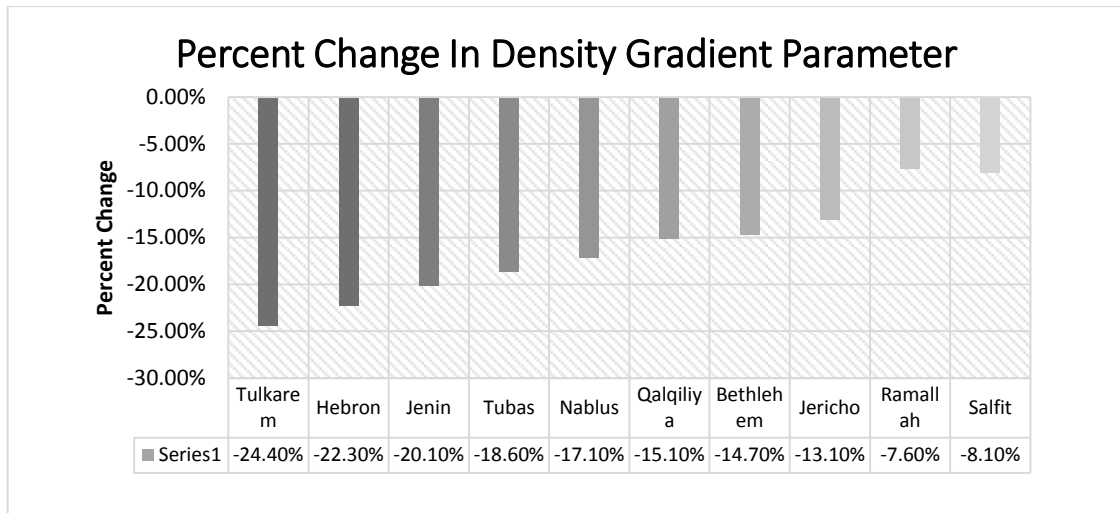


Figure 24: Percent change in density gradient parameter

- **Ranking**

As a pattern

Table 13 : Ranking of the urban areas according to λ values in 2017 from the highest to lowest sprawl

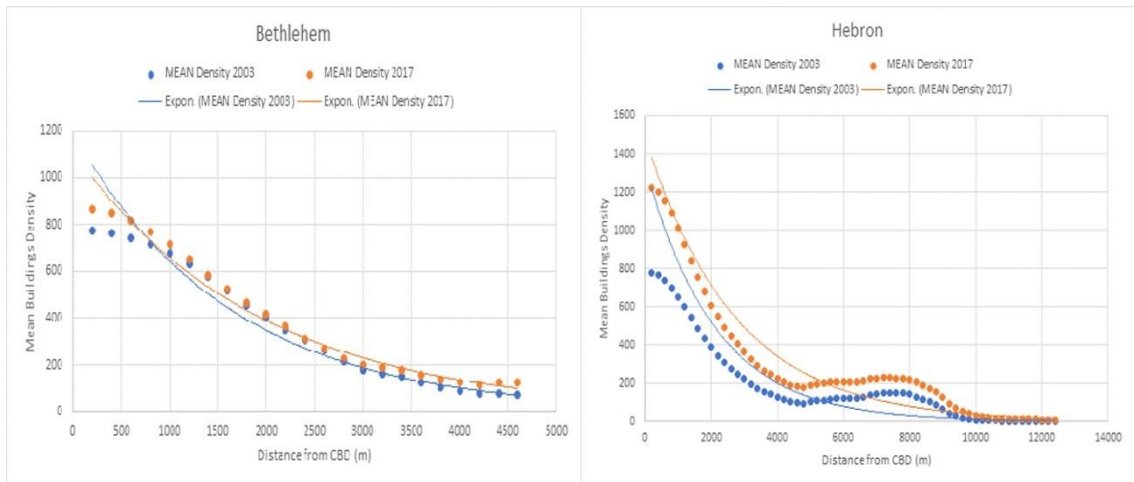
Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area
Hebron	Nablus	Bethlehem	Ramallah	Qalqiliya	Jenin	Jericho	Tulkarem	Salfit	Tubas
0.00037	0.00045	0.00053	0.00061	0.00082	0.00093	0.00096	0.00099	0.00123	0.00163

As a process

Table 14 : Ranking urban areas according to change in λ between 2003 and 2017 values from the most changing to the least changing

Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area	Urban Area
Tulkarem	Hebron	Jenin	Tubas	Nablus	Qalqiliya	Bethlehem	Jericho	Salfit	Ramallah
24.40%	22.30%	20.10%	18.60%	17.10%	15.10%	14.70%	13.10%	8.10%	7.60%

The density gradient graphs also show a negative relationship between buildings density and distance from the main urban center for all urban areas under study. This indicates that all Palestinian urban areas have strong and dense urban cores.



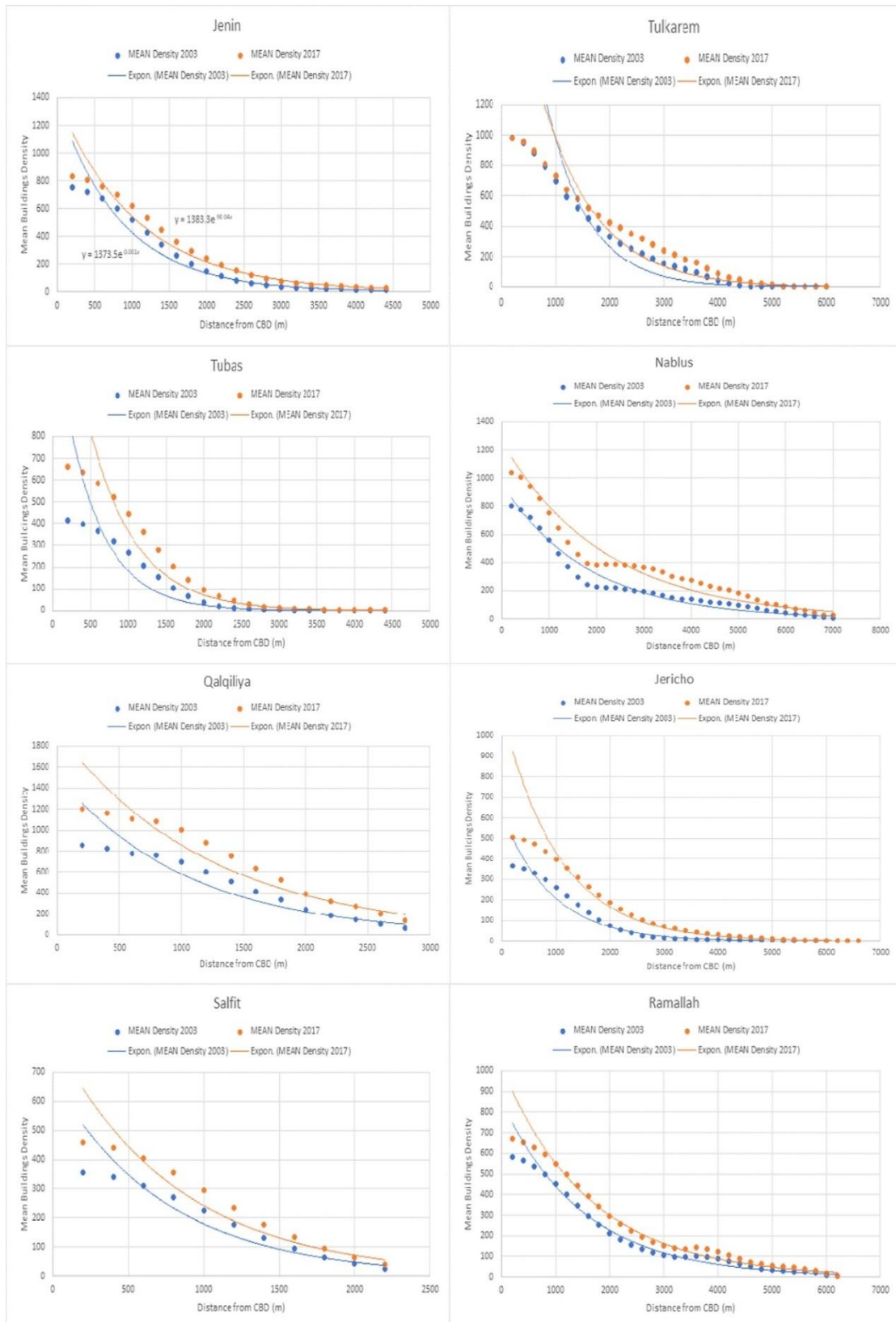


Figure 25: Density gradient graphs for all urban area between 2003 and 2017: Urban sprawl represents a decline, or “flattening” of the density gradient curve over a specific period.

4.1.2 Urban Growth Dimension

A. Growth Rates of Population Versus Built-up Area

A black and white hypothetical approach for determination of sprawl considered by scholars is: If spatial growth of builtup area exceeds population growth, it's an indication of sprawl (Burgess and Thomas,1997; Glaeser and Kahn, 2003; Lopez and Hynes, 2003; Bhatta, 2010; Sudhira and Ramchandra, 2004; Ewing et al., 2002; Burgess and Thomas, 1997; Fulton et al., 2001; Barnes et al., 2001; Gordon and Richardson, 1997). A sprawl index is defined as the ratio of the increase in built-up areas to the increase in population in that area between 2003 and 2017. A quotient higher than 1 implies urban sprawl (Hadly, 2000, Weitz, 1999 as cited in Frenkel et al., 2008)

- **Results**

Table 15: Growth rates of population VS growth rates of builtup area

Urban Area	Percent change in builtup area	Percent change in Population	Index
Jericho	125%	22%	5.73
Nablus	78%	39%	2.01
Tubas	96%	52%	1.86
Tulkarem	65%	40%	1.62
Jenin	69%	44%	1.57
Hebron	57%	43%	1.33
Bethlehem	41%	33%	1.27
Qalqilya	39%	37%	1.05
Salfit	33%	37%	0.90
Ramallah	33%	49%	0.68

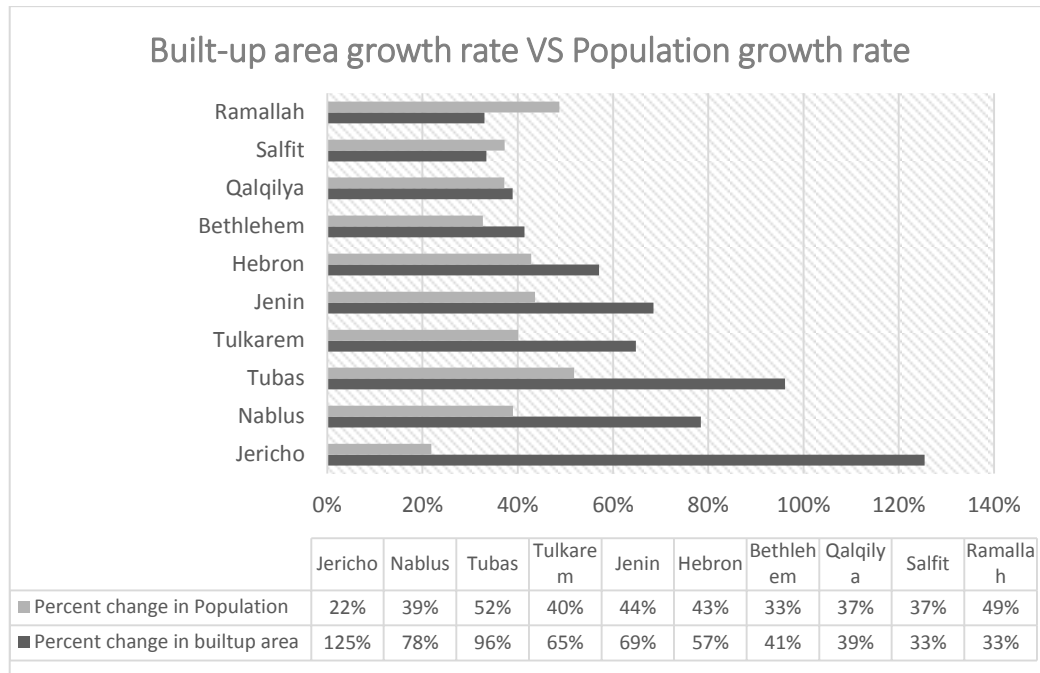


Figure 26: Built-up area growth rate VS Population growth rate

• Discussion

The table above illustrates the value of the index for the 10 urban areas. 8 out of the 10 areas recorded values above 1, indicating a sprawling trend. However, these values were varied and distinct. Jericho area has recorded the highest sprawl value of 5, meaning that the urban built up area of the city has increased 5 times larger than the actual population need (or increase). Nablus city came in the second order, where its urban area doubled compared to its population increase. The rest of the urban areas were also outpacing their population increase with different levels except for Ramallah and Salfit. The lowest value in Ramallah is perhaps a result of the vertical development dominating the city structure, which compensate the need for land for horizontal expansion.

- **Ranking:** (both as a pattern and a process) since growth is dynamic

Table 16: Ranking urban areas according to their growth rates

parameter values from the highest to lowest sprawl (left to right)

Jericho	Nablus	Tubas	Tulkarem	Jenin	Hebron	Bethlehem	Qalqilya	Salfit	Ramallah
5.73	2.01	1.86	1.62	1.57	1.33	1.27	1.05	0.9	0.68

B. Growth Patterns

Provide a measure of the type of growth occurring in the urban area. Three types of urban growth are defined : The infill pattern, the expansion pattern, and the outlying patterns. Outlying growth indicates urban sprawl (Wilson et al., 2003). Since this analysis doesn't make a distinction between low density or high-density extension growth, the index for sprawl for this measure will be obtained from the percentage of outlying pattern. For the ranking, if the percentage of new infill growth is higher than expansion growth, the city will be considered as non-sprawling with regards to this parameter.

- **Results**

Table 17 : Percentages of growth types between 2003 and 2017 for each urban area

Urban Area	In-fill growth percentage	Extension growth percentage	Outlying growth percentage
Bethlehem	31%	47%	21%
Jericho	20%	60%	19%
Ramallah	34%	47%	19%
Tubas	38%	46%	16%
Jenin	19%	67%	14%
Tulkarem	7%	85%	8%
Salfit	53%	41%	6%
Hebron	51%	44%	5%
Nablus	44%	54%	2%
Qalqilya	72%	27%	1%

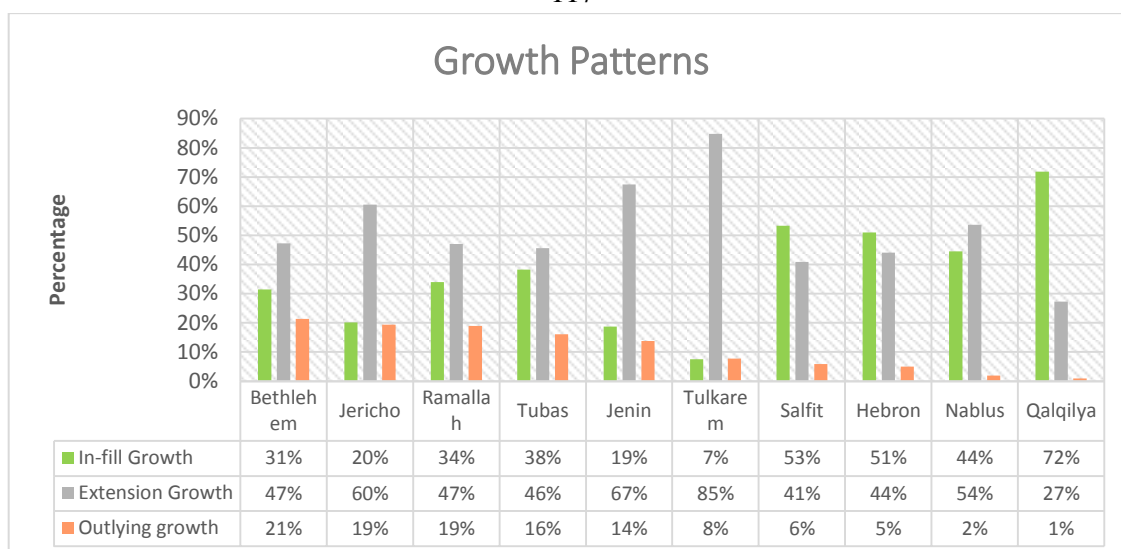


Figure 27 : Percentages of growth types between 2003 and 2017 for each urban area.

• Discussion

The graph above summarizes the percentages of each of the 3 types of growth occurred in the period between 2003 and 2017. By looking at each type of growth on its own we can notice that extension growth (in grey) dominated the growth in 7 areas out of 10. These areas are ordered - with regards to percentage of extension growth from highest to lowest – as follows: Tulkarem, Jenin, Jericho, Nablus, Bethlehem, Ramallah and Tubas. The rest of the cities have been dominated by in fill growth with the highest level recorded in Qalqilya, followed by Salfit, and Hebron respectively. Outlying growth was the least type for all urban areas, but with different percentages. The highest percentage of outlying growth is observed in Bethlehem, followed by Jericho, Ramallah, Tubas, and Jenin which were relatively higher than the rest of the urban areas including Tulkarem, Salfit, Hebron, Nablus and finally Qalqilya, with the lowest percentage of outlying growth.

The highest percentages of infill growth which happened in cities of Qalqilya, Salfit and Hebron, can be related to the limited lands for expansion due to political situation, land subdivision and Israeli colonies, which is highly evident in the three of the urban areas. Other areas where extension pattern dominated growth are less restricted by geopolitical situation, leading to their edge expansion. Outlying growth which is considered a significant sprawl is noticed to be relatively high in areas with a proximity to Jordan Valley at the east part of the West Bank.

The following table ranks each type of growth from the highest to lowest values in each urban area. Outlying growth percentage will be used as the indicator of sprawl.

Table 18 : Ranking urban areas according to the values of each type of growth

Urban Area	In-fill growth percentage	Urban Area	Extension growth percentage	Urban Area	Outlying growth percentage
Qalqilya	72%	Tulkarem	85%	Bethlehem	21%
Salfit	53%	Jenin	67%	Jericho	19%
Hebron	51%	Jericho	60%	Ramallah	19%
Nablus	44%	Nablus	54%	Tubas	16%
Tubas	38%	Bethlehem	47%	Jenin	14%
Ramallah	34%	Ramallah	47%	Tulkarem	8%
Bethlehem	31%	Tubas	46%	Salfit	6%
Jericho	20%	Hebron	44%	Hebron	5%
Jenin	19%	Salfit	41%	Nablus	2%
Tulkarem	7%	Qalqilya	27%	Qalqilya	1%

- **Ranking (both as pattern and a process)**

Table 19: Ranking urban area according to their outlying growth pattern percentages from the highest to lowest sprawl

Urban Area	Bethlehem	Jericho	Ramallah	Tubas	Jenin	Tulkarem	Salfit	Hebron	Nablus	Qalqilya
Outlying growth percentage	21%	19%	19%	16%	14%	8%	6%	5%	2%	1%

4.1.3 Spatial Geometry Indicators of Urban Form

- **Measures of Complexity:**

Sprawl is usually characterized by complex, Irregular and fragmented urban form patterns. The increase in shape complexity with time is considered an indication of sprawling development. a single landscape measure cannot capture all the geometric properties of the urban area (Li, 2012) ; hence, the complexity of built up area for each city in the analysis was calculated using three parameters (indicators) of shape complexity, stemmed from landscape ecology. These measures were calculated both as a pattern and a process by assessing the change in their value from 2003 to 2017. An increase in complexity of the urban area from 2003 to 2017 indicates a tendency towards urban sprawl.

A. Fractal Dimension

Fractal Dimension

$$D \approx 2 \frac{\log P}{\log A}$$

Measure of built up area complexity based on perimeter-area relationship. The value of D ranges between 1 and 2. Values closer to 1 reflect simpler Euclidean shapes, such as circle and squares, whereas values closer to 2 indicates complex shapes with more space filling edges and higher amounts of sprawl, such as star, rectangle or linear forms.

- **Results**

Table 20 : Fractal dimension values in 2003 and 2017

Urban Area	Fractal Dimension 2003	Fractal Dimension 2017	Percent Change %	Sprawl Indicator
Hebron	1.332	1.369	2.82%	+
Tubas	1.334	1.352	1.35%	+
Jericho	1.343	1.351	0.56%	+
Jenin	1.324	1.345	1.56%	+
Tulkarem	1.352	1.340	-0.89%	-
Nablus	1.352	1.337	-1.09%	-
Ramallah	1.331	1.333	0.14%	+
Bethlehem	1.354	1.318	-2.66%	-
Salfit	1.298	1.288	-0.79%	-
Qalqilya	1.243	1.269	2.04%	+

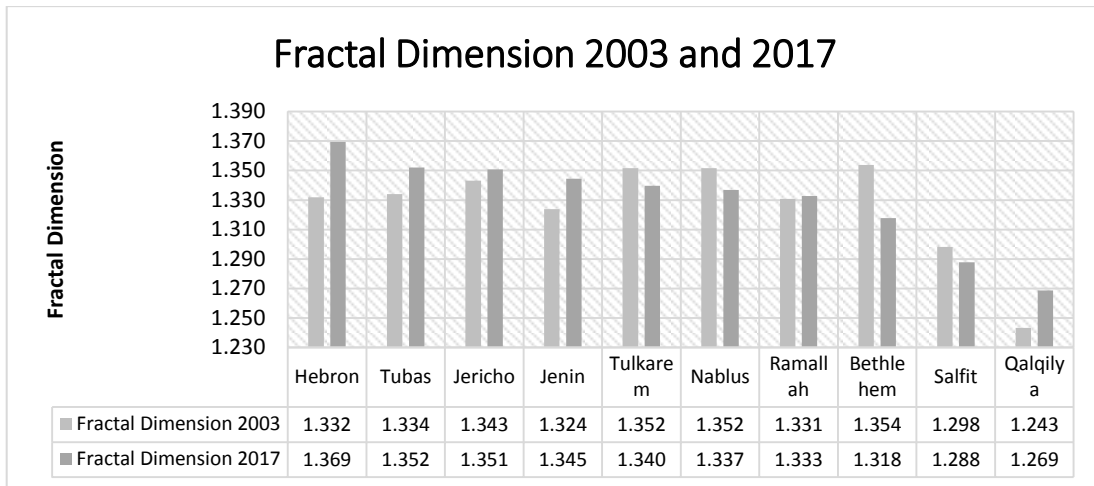


Figure 28: Fractal Dimension in 2003 and 2017

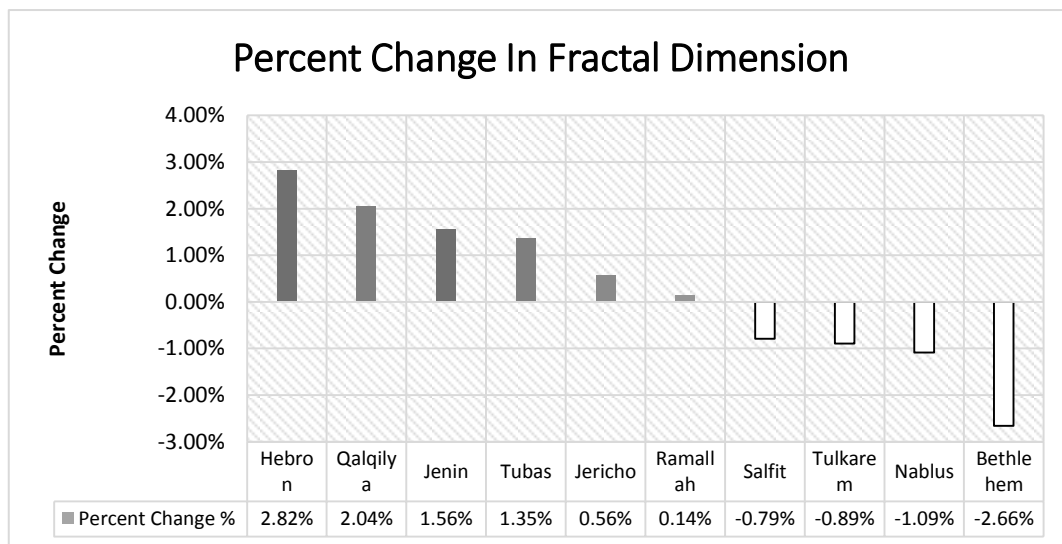


Figure 29: Percent change in fractal dimension

• Discussion

Increasing fractal dimension is evaluated as a reflection of a sprawling process (Terazi, 2008 as cited in Li, 2012). The fractal dimension is used to analyse the change in spatial configuration of the built-up area from 2003 to 2017. A conclusion can be drawn from the above results as follows:

The values of fractal dimension for the 10 urban areas in Palestine ranged between 1.2 and 1.4, which are closer to 1 than 2 (knowing that this measure is calculated for the main consolidated patch of each urban area) . This indicates that in general , the main built-up patches for all urban areas can be classified as simple shapes . For Tulkarem, Nablus, Bethlehem and Salfit, the fractal dimension has slightly decreased from 2003 to 2017 indicting a decrease in shape complexity . This decrease may result from edge filling through time, and annexation of built-up areas. By contrast, the other urban areas have increased in their shape complexity through time , indicating a tendency towards sprawl. This increase can be an indication of unplanned and irregular growth, and an outlying or linear stripe growth which increases the perimeter on the account of area .

Comparing the urban areas in their complexity values in 2017, we can notice that Hebron, Tubas, Jericho are on the top of the list with higher complex built-up areas than other cities . Qalqilya and Salfit are the lowest in complexity since their shapes have more simple forms.

The limited boundary of expansion resulting from the geopolitical situation, which is evident in Qalqilya and Salfit, have resulted in high percentages of space filling and edge filling growth leading to a simpler form with time. By contrast, in Jericho, Tubas and Hebron , where boundaries are less restricted and closer to Jordan Valley, expansion growth have been characterized by irregular shapes resulting in higher complexity in comparison to other Palestinian cities . Whereas the most

three changing areas towards complex structure from 2003 to 2017 are Hebron, followed by Qalqilya, and Jenin.

- **Ranking**

As a pattern

Table 21: Ranking urban areas according to fractal dimension values in 2017 from the highest to lowest sprawl

Urban Area	Hebron	Tubas	Jericho	Jenin	Tulkarem	Nablus	Ramallah	Bethlehem	Salfit	Qalqilya
Fractal Dimension 2017	1.369	1.352	1.351	1.345	1.34	1.337	1.333	1.318	1.288	1.269

As a process

Table 22: Ranking urban areas according to change in fractal dimension between 2003 and 2017 from the most to least changing (urban areas in bold has lower fractal dimension in 2017)

Urban Area	Hebron	Qalqilya	Jenin	Tubas	Jericho	Ramallah	Salfit	Tulkarem	Nablus	Bethlehem
Percent Change	2.82%	2.04%	1.56%	1.35%	0.56%	0.14%	-0.79%	-0.89%	-1.09%	-2.66%

B. Shape Index

Shape Index

$$Shape = \frac{Pi}{\min Pi}$$

Measure shape complexity with regards to an optimum circle with the same area. . Higher shape index values indicate more complex structure and higher amounts of sprawl. Lower shape index values indicate shapes closer to circle shape and lower shape complexity

- **Results**

Table 23: Shape Index values in 2003 and 2017

Urban Area	Shape Index 2003	Shape Index 2017	Percent Change %	Sprawl Indicator
Hebron	3.9	7.1	80.03%	+
Nablus	4.2	4.9	16.23%	+
Jenin	3.2	4.5	39.92%	+
Tulkarem	3.6	4.5	25.40%	+
Ramallah	3.5	4.3	23.57%	+
Tubas	3.1	4.0	28.40%	+
Jericho	3.4	3.9	15.18%	+
Bethlehem	5.0	3.9	-21.69%	-
Salfit	2.5	2.4	-3.70%	-
Qalqilya	1.8	2.2	27.29%	+

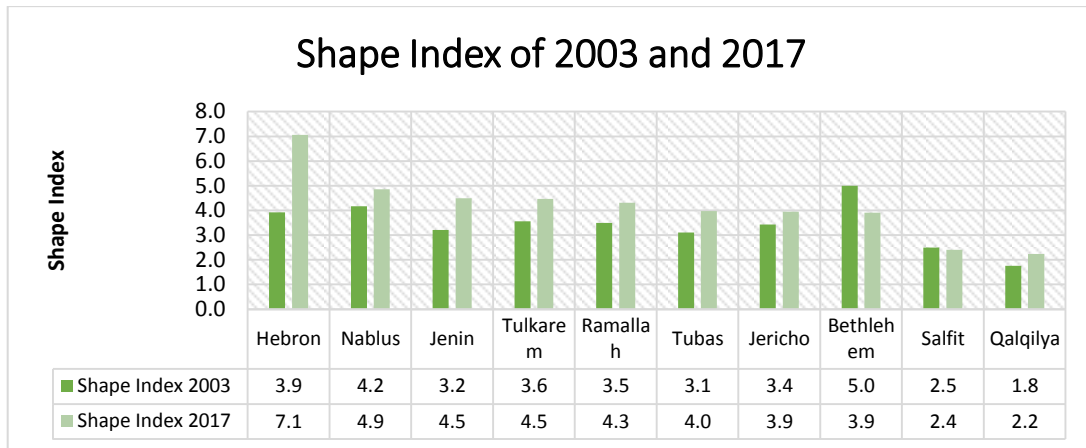


Figure 30 : Shape Index values in 2003 and 2017

• Discussion

Another measure of shape complexity, this time by comparing the urban form with a circle form, which is considered the most compact and sustainable form of development. Similar to the previous measure “fractal dimension”, the least complex urban forms were in Qalqilya and Salfit, whereas the most complex forms of all areas were in Hebron, Nablus and Jenin. Nablus area has an elongated, rectangle shape, thus for this parameter, which is a measure of circularity, Nablus came in the second place after Hebron.

The change in the value of the shape index between the two years is also measured. Bethlehem and Salfit, became more circular in form with time whereas the rest of the urban areas became less circular and more complex in form. The most changing urban areas towards sprawl for this index were Hebron, Jenin and Tubas respectively.

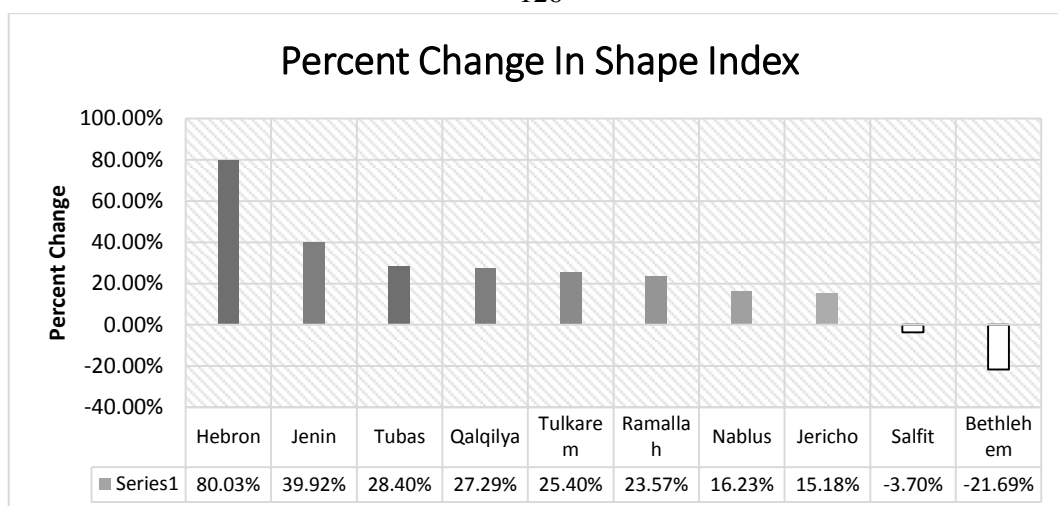


Figure 31 : Percent change in shape index

- **Ranking**

As a pattern (from the highest to lowest complex in 2017)

Table 24: Ranking the urban areas according to shape index values in 2017 from the highest to lowest sprawl

Urban Area	Hebron	Nablus	Jenin	Tulkarem	Ramallah	Tubas	Jericho	Bethlehem	Salfit	Qalqilya
Shape Index 2017	7.1	4.9	4.5	4.5	4.3	4	3.9	3.9	2.4	2.2

As a process (from the most changing to least changing)

Table 25: Ranking urban areas according to change in Shape index between 2003 and 2017 from the most to least changing

Urban Area	Hebron	Jenin	Tubas	Qalqilya	Tulkarem	Ramallah	Nablus	Jericho	Salfit	Bethlehem
Percent Change %	80.03%	39.92%	28.40%	27.29%	25.40%	23.57%	16.23%	15.18%	-3.70%	-21.69%

C. Compactness Index

$$\text{Compactness} = \frac{\text{builtup area within}}{\text{buildable area within}}$$

Provides a measure of the overall patch elongation, or the extent to which the area fills its two-dimensional space. The greater the compactness, the more concentrated the urban form is, and the lower the sprawl.

- **Results**

Table 26: Compactness index values in 2003 and 2017

Urban Area	Compactness Index 2003	Compactness Index 2017	Percent Change %	Sprawl Indicator
Nablus	0.23	0.23	0.08%	+
Jenin	0.31	0.29	-5.33%	-
Tubas	0.31	0.32	1.05%	+
Jericho	0.29	0.32	10.66%	+
Bethlehem	0.25	0.34	32.96%	+
Hebron	0.45	0.36	-20.15%	-
Tulkarem	0.32	0.40	26.12%	+
Salfit	0.37	0.42	14.30%	+
Ramallah	0.35	0.44	27.64%	+
Qalqilya	0.64	0.58	-9.05%	-

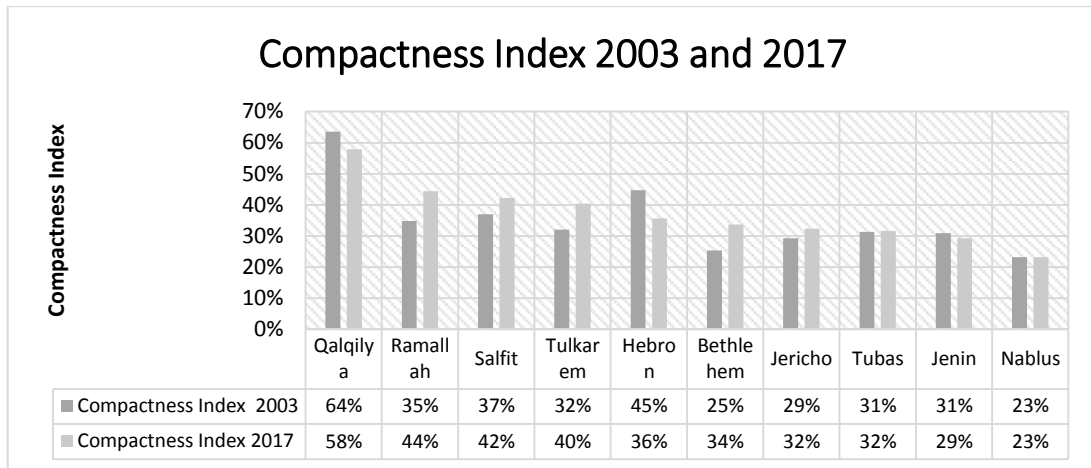


Figure 32: Compactness index values in 2003 and 2017

• Discussion

This measure of shape summarizes the space filling property of built up areas and investigate to what extent are compact, fully built, and resemble a circular shape. The compactness index of Qalqilya (which has the highest compactness index of all areas) in 2003 was 0.64 meaning that 0.64 percent of the buildable area in the circle of minimum radius surrounding the main built-up area was built. This value decreased in 2017 to be 0.58, indicating that the built-up area of Qalqilya has become less concentrated with time, thus an indication of sprawl. The lowest compactness value is observed in Nablus city, which has the most elongated and linear urban form due to its geographic location and topography constrains. Linear forms are classified among the most sprawling urban forms, since they have the lowest centralization and accessibility to urban center. The moderate values of compactness hovering around 0.4 implies that urban areas have an ample space for infill development without pushing the limits of their boundaries away from the main center. This would be applicable in

the case of a stable geopolitical situation, without land confiscation and political subdivision. Most of the empty areas are existed in area c which is not controlled by PA.

The change in compactness value from 2003 to 2017 varied between cities. Three out of 10 cities have decreased in their compactness through the 14 years period including Hebron with the highest percentage of decrease, followed by Qalqilya and Jenin. Hence, the growth of the three cities can be characterized by irregular expansion into the landscape indicating a sprawling pattern. The rest of the urban areas have increased in their compactness with different levels indicating edge filling and infilling growth. The reason that the majority of urban areas have increased in compactness can be attributed to the geopolitical restrictions represented in the limited spaces for expansion growth .

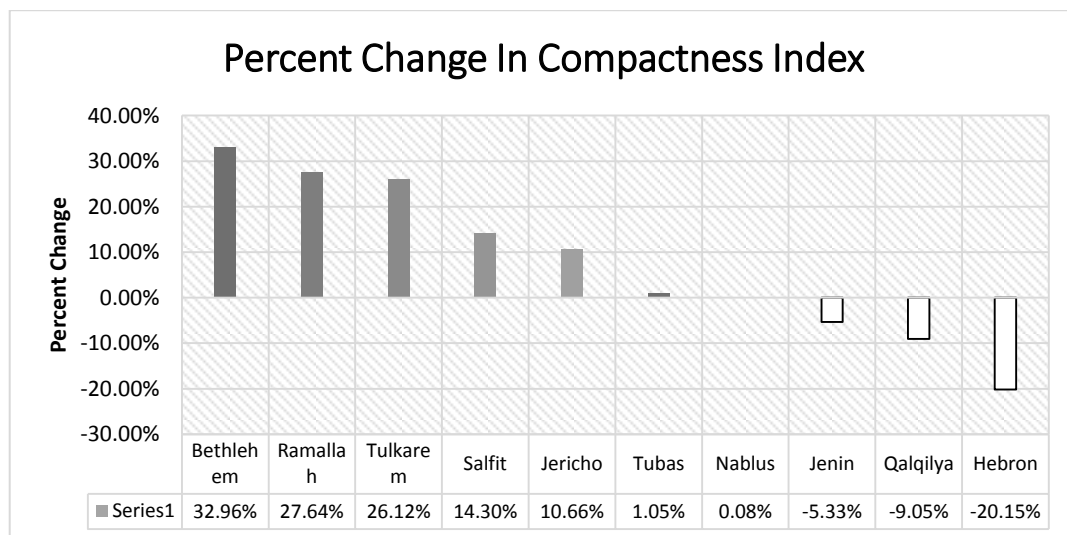


Figure 33: Percent change in compactness index

- **Ranking**

As a pattern (worst to best)

Table 27: Ranking the urban areas according to compactness index values in 2017 from the highest to lowest sprawl

Urban Area	Nablus	Jenin	Tubas	Jericho	Bethlehem	Hebron	Tulkarem	Salfit	Ramallah	Qalqilya
Compactness Index 2017	0.23	0.29	0.32	0.32	0.34	0.36	0.4	0.42	0.44	0.58

As a process (worst to best)

Table 28 : Ranking urban areas according to change in compactness index between 2003 and 2017 from the most to least changing

Urban Area	Hebron	Qalqilya	Jenin	Nablus	Tubas	Jericho	Salfit	Tukaram	Ramallah	Bethlehem
Percent Change in compactness %	- 20.15 %	- 9.05 %	- 5.33 %	0.08 %	1.05 %	10.66 %	14.30 %	26.12 %	27.64 %	32.96%

- **Measures of fragmentation:**

D. Contiguity Index

Contiguity Index

$$Contiguity = \frac{Bm}{Bs}$$

A possible measure of the extent to which the city is monocentric rather than polycentric. It's given as the percentage of area comprising the largest patch in the city. The higher the value, the more monocentric the

city is, and the lower the sprawl. very low contiguity values indicate the absence of spatial structure, and high amounts of sprawl (Angel et al, 2005).

- **Results**

Table 29: Contiguity index values in 2003 and 2017

Urban Area	Contiguity Index 2003	Contiguity Index 2017	Percent Change %	Sprawl Indicator
Qalqilya	0.99	1.00	0.91%	+
Salfit	0.99	0.99	-0.60%	-
Nablus	0.76	0.98	29.20%	+
Bethlehem	0.96	0.95	-0.69%	-
Jenin	0.84	0.95	13.52%	+
Hebron	0.72	0.95	31.77%	+
Tulkarem	0.66	0.94	42.12%	+
Tubas	0.91	0.91	-0.05%	-
Ramallah	0.71	0.89	25.01%	+
Jericho	0.78	0.72	-8.29%	-

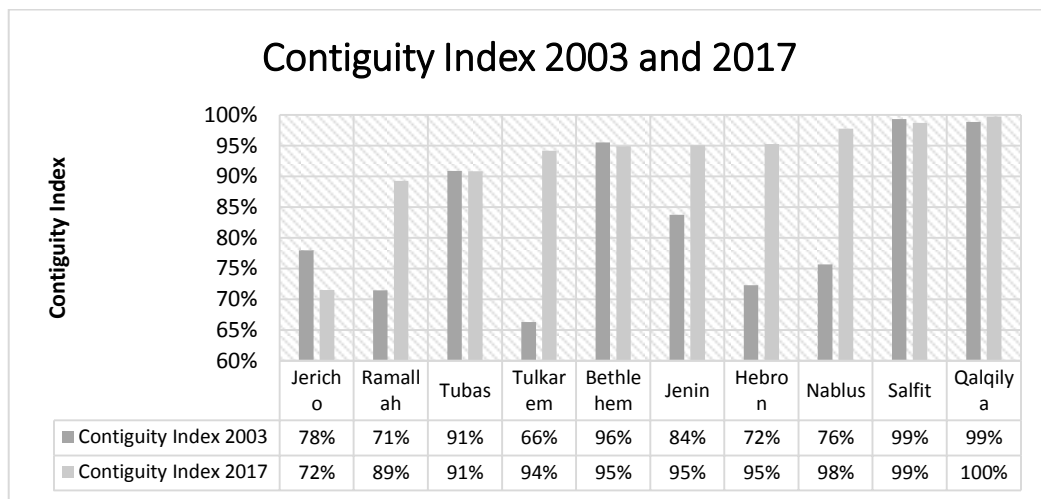


Figure 30: Contiguity index values in 2003 and 2017

- **Discussion**

The measure of contiguity helps to better understand if a city is more clumped and monocentric rather than other cities; furthermore, it helps to determine if urban areas are becoming more monocentric or polycentric with time by assessing **the size of the main urban** patch with regards to the total built-up area (Angel et al, 2005) . First, the comparison of the contiguity index for Palestinian cities in 2017 which illustrates the pattern of sprawl has drawn the following conclusions: Qalqilya city is on the top of the list as the most contiguous city with an index of 1, since its built-up area is formed of a 1 large urban patch; followed by Salfit and Nablus which came in the second and third place with a 0.99 and 0.98 percent implying that their main built-up patch forms 99% and 89% of their total built up area . The lowest contiguity values are found in Jericho with 0.72, implying that the main urban patch forms only 72% of the total built up area of the city. Followed by Ramallah and Tubas with 0.89 and 0.91 respectively.

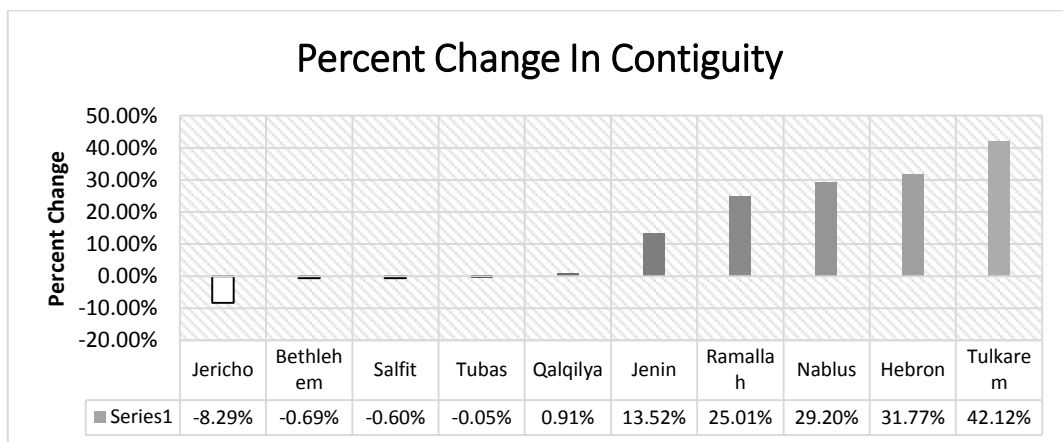


Figure 34: Percent change in contiguity index

With regards to the process of sprawl, contiguity index has increased in 6 out of the 10 areas, meaning that their built-up area became less fragmented and more consolidated with time due to infill growth which takes place in the gaps of the already built space, and annexation policies resulting from extension growth and the fusion of urban and rural areas. The Index have increased the most in Tulkarem, Hebron, and Nablus. This increase is reflected by the urban-rural annexation, which is evident in all of the three cities

The rest of cities, who's decreased in their contiguity from 2003 to 2017, include Jericho, with a relatively high decrease compared to others, Bethlehem, Tubas and Salfit with a very small decrease. This decrease is caused by the new outlying urban patches emerged during the time period especially in Jericho area.

In General, it can be noticed that contiguity index values of Palestinian cities hover around 0.9- except for Jericho- which are considered high values, indicating a well-structured and a monocentric urban form. It can also be concluded that the change in the index is dominated by positive change towards being more contiguous with time; and the rest had minor negative change. This may be attributed to several factors including the most and the foremost reason for limiting the outer growth of Palestinian cities represented in the Israeli siege in WB which have set cities in isolation from each other.

- **Ranking**

As a pattern (worst to best)

Table 310: Ranking the urban areas according to contiguity index values in 2017 from the highest to lowest sprawl

Urban Area	Jericho	Ramallah	Tubas	Tulkarem	Bethlehem	Jenin	Hebron	Nablus	Salfit	Qalqilya
Contiguity Index 2017	0.72	0.89	0.91	0.94	0.95	0.95	0.95	0.98	0.99	1

As a process (worst to best)

Table 321: Ranking urban areas according to change in contiguity index between 2003 and 2017 from the most to least changing

Urban Area	Jericho	Bethlehem	Salfit	Tubas	Qalqilya	Jenin	Ramallah	Nablus	Hebron	Tulkarem
Percent Change %	-8.29 %	-0.69 %	-0.60 %	-0.05 %	0.91 %	13.52 %	25.01 %	29.20 %	31.77 %	42.12 %

E. Number of Patches (Patchiness)

The previous measure of contiguity helps in determining if cities are more **monocentric or polycentric**. However, the measure on its own is insufficient in summarizing the spatial structure of the urban form. Two cities with the same contiguity value , may differ in patchiness (the number of patches) which is another important spatial feature of sprawl . The contiguity measure looks at the size of the main patch only, whereas

this measure is concerned with the **number of patches**, hence this measure and the previous measure are complementary.

Number of Patches (NP)

A measure of discontinuity of urban patches. The greater the patchiness, the more fragmented the landscape is, and the higher the sprawl. This metric provides an indication on the number of new built-up patches created in time (Herold et, al. 2002). If the number of patches decrease over time , urban area becomes more contiguous and less fragmented , thus less sprawling.

- **Results**

Table 32: NP values in 2003 and 2017

Urban Area	NP 2003	NP 2017	Percent Change %	Sprawl Indicator
Tulkarem	26	23	-11.54%	-
Hebron	76	86	13.16%	+
Bethlehem	32	37	15.63%	+
Nablus	23	31	34.78%	+
Qalqilya	2	3	50.00%	+
Ramallah	25	48	92.00%	+
Jenin	18	43	138.89%	+
Jericho	27	65	140.74%	+
Salfit	3	8	166.67%	+
Tubas	11	36	227.27%	+

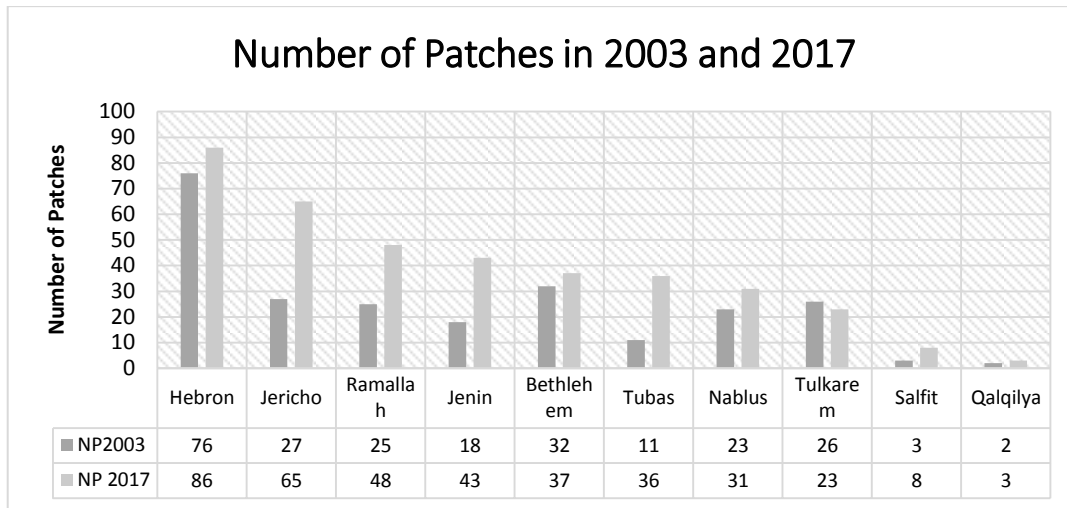


Figure 35: NP values in 2003 and 2017

• Discussion

Although this measure is simple and direct. It still gives an important insight on the amounts of scattering and fragmentation happening in the urban landscape. A look at the table of results conclude the following with regards to the pattern of sprawl: Hebron came in the first place with the highest amounts of built patches, indicating the highest level of fragmented urban landscape. Jericho, and Ramallah came in the second and third place with high fragmentation in their built-up area and relatively high amounts of sprawl. As expected, Qalqilya city had the lowest NP value , followed by Salfit and Tulkarem indicating a relatively low amounts of outlying sprawl.

The change in patchiness from 2003 to 2017 has been dominated by the increase of the index value. 9 out of the 10 areas have increased in their number of new built-up patches that are non-contiguous to their main built-up area and fragmented from each other. The highest increase in patchiness

is observed in Tubas indicating a relatively high amounts of scattered development patterns, followed by Salfit and Jericho in the second and third place. Tulkarem area has decreased in its patchiness from 2003 to 2017, indicating a coalition process and less sprawling attitude.

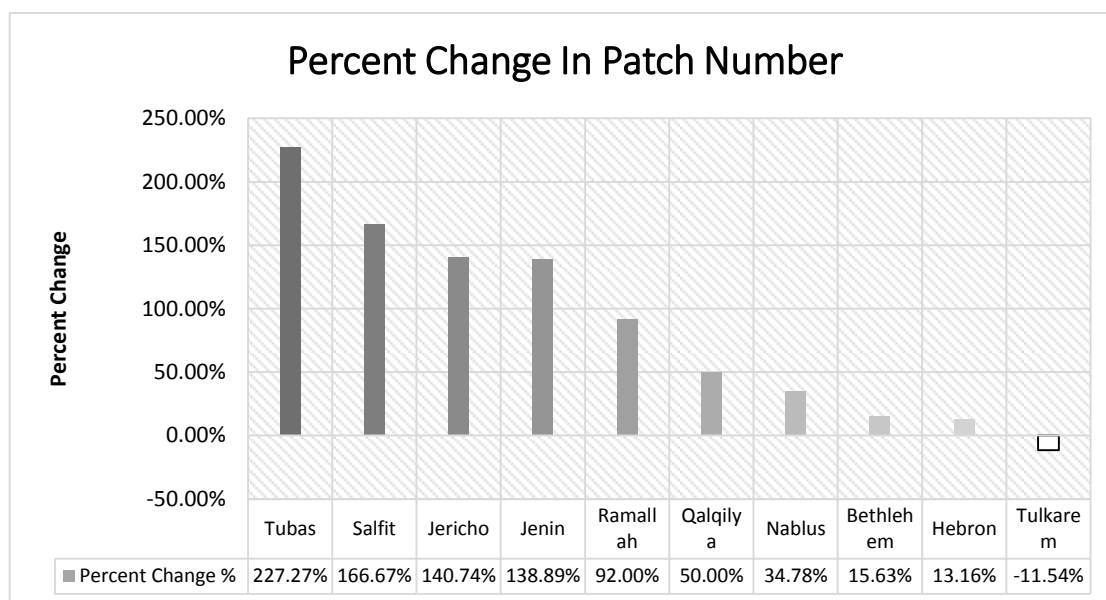


Figure 36: Percent change in patch number

- **Ranking**

As a pattern (worst to best)

Table 33: Ranking the urban areas according to number of patches values in 2017 from the highest to lowest sprawl

Urban Area	Hebron	Jericho	Ramallah	Jenin	Bethlehem	Tubas	Nablus	Tulkarem	Salfit	Qalqilya
NP 2017	86	65	48	43	37	36	31	23	8	3

As a process (worst to best)

Table 34: Ranking urban areas according to change in number of patches index between 2003 and 2017 from the most to least changing

Urban Area	Tubas	Salfit	Jericho	Jenin	Ramallah	Qalqilya	Nablus	Bethlehem	Hebron	Tulkarem
Percent Change	227.27%	166.67%	140.74%	138.89%	92.00%	50.00%	34.78%	15.63%	13.16%	-11.54%

F. Scatter

Scatter

$$S = \sum_{i=1}^n \frac{(H_i E_i)}{H}$$

A measure of the degree of scattering of the builtup areas. Higher scatter values indicate higher sprawl, whereas lower scatter values indicate lower sprawl, and more compact forms.

- **Results**

Table 35: Scatter parameter values in 2003 and 2017

Urban area	Scatter 2003	Scatter 2017	Percent Change	Sprawl Indicator
Hebron	3078	3236	5%	+
Nablus	2262	2530	12%	+
Ramallah	2089	2216	6%	+
Jericho	1420	2027	43%	+
Bethlehem	1877	1945	4%	+
Tulkarem	1451	1664	15%	+
Jenin	1170	1437	23%	+
Tubas	735	1178	60%	+
Qalqilya	653	734	12%	+
Salfit	557	661	19%	+

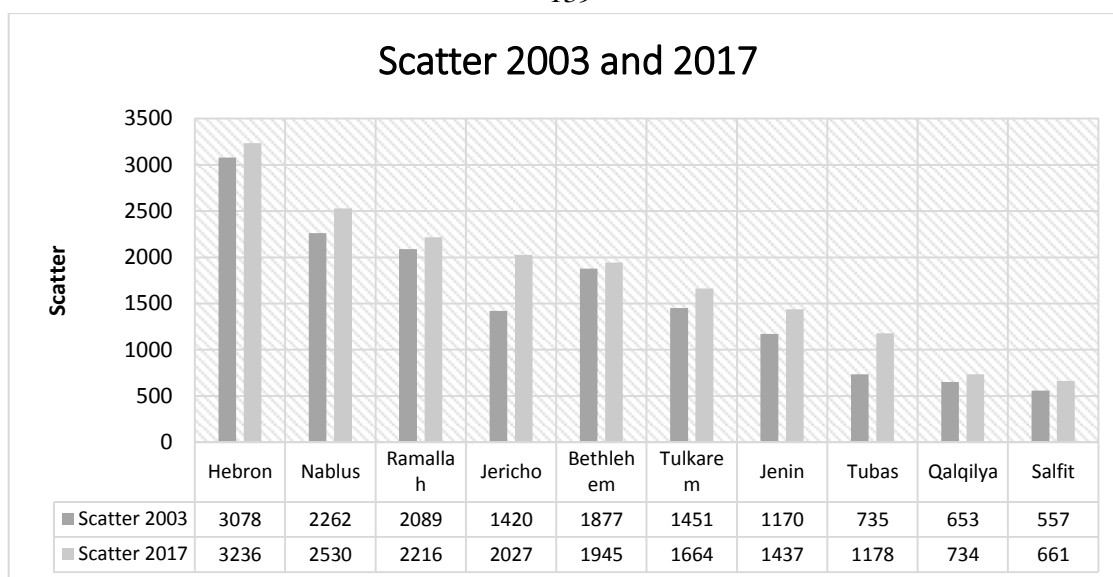


Figure 37: Scatter parameter values in 2003 and 2017

• Discussion

The measure helps in understanding the scattered characteristics of sprawl which manifest themselves in various ways including fragmentation, leapfrogging, dispersion, or discontinuous development (Torrens and Alberti, 2000) which all are considered unsustainable and costly. The two previous measures of fragmentation (contiguity and patchiness) are concerned with size and number of patches, while this measure is concerned with the spatial relations of these patches (proximity and distance).

By looking at the results in the table above, Hebron area came in first place with the highest scatter value in 2017. Nablus and Ramallah came in the second and third place, indicating a high dispersion of the urban area from the mean center. The lowest scatter values were in Salfit, Qalqilya and Tubas. It can be noted that the value of scatter positively correlates with

the urban area size. Larger urban areas such as Hebron and Nablus have larger index value, by contrast, smaller areas such as Salfit and Tubas had the lowest index values.

The process of scattering between 2003 and 2017 have increased in all urban areas with varying proportions. The highest was in Tubas with a dramatic 60% increase. Jericho and Jenin were ranked as the second and third highest increase values with 43% and 23% respectively. One can notice from the map of Tubas and Jericho, that these areas have witness a significant increase in outlying and leapfrogging growth, an increase in patchiness and a decrease in contiguity, which all explains a relatively high sprawling attitude, whereas Bethlehem, Hebron and Ramallah were the lowest in increase value.

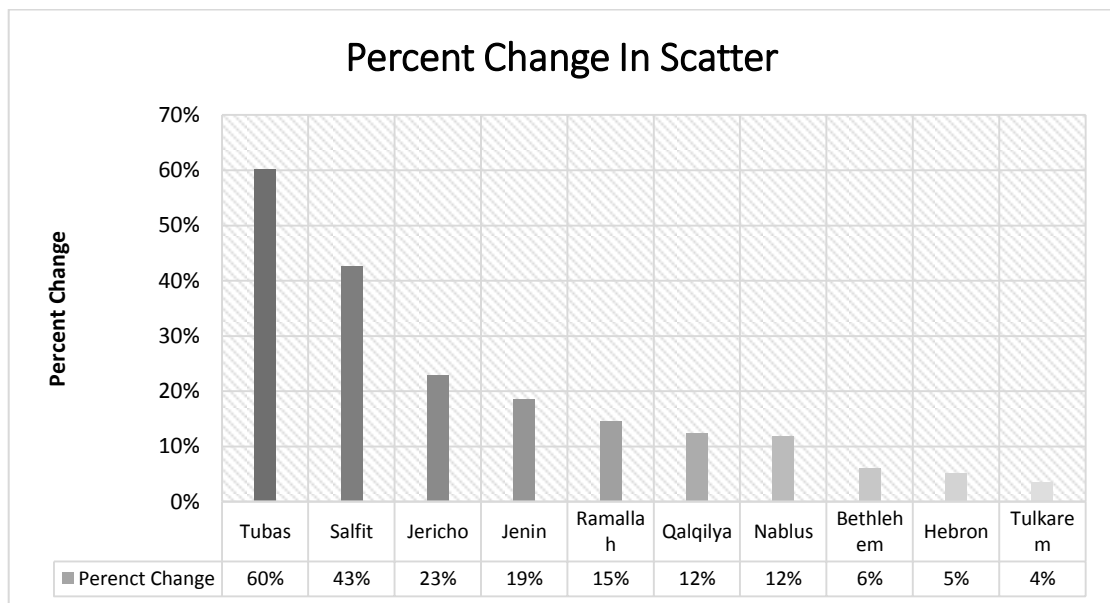


Figure 38: Percent change in scatter values

- **Ranking**

As a pattern (worst to best)

Table 36: Ranking the urban areas according to scatter values in 2017 from the highest to lowest sprawl

Urban Area	Hebron	Nablus	Ramallah	Jericho	Bethlehem	Tulkarem	Jenin	Tubas	Qalqilya	Salfit
Scatter 2017	3236	2530	2216	2027	1945	1664	1437	1178	734	661

As a process (worst to best)

Table 37: Ranking urban areas according to change in scatter index between 2003 and 2017 from the most to least changing

Urban Area	Tubas	Jericho	Jenin	Salfit	Tulkarem	Qalqilya	Nablus	Ramallah	Hebron	Bethlehem
Percent Change	60%	43%	23%	19%	15%	12%	12%	6%	5%	4%

G. Shannon Entropy

The final measure of configuration is Shannon entropy and its concerned with the distribution of built-up area patches across the landscape. As explained earlier, each of the four measures is concerned with a certain dimension of patches (size, number, distance and distribution), in this sense, the four measures are complementary.

$$E = \sum_i^n P DEN_i * \log\left(\frac{1}{P DEN_i}\right) / \log n$$

Shannon Entropy

Where

$$P DEN_i = DEN_i / \sum_i^n P DEN_i$$

Measures the degree of spatial concentration or dispersion of the geographic variable among zones of the urban area. For the relative entropy, values closer to 0 indicates maximum compaction of the variable, and values closer to 1 indicates dispersed distributions of the variable across the landscape.

- **Results**

Table 38: Shannon entropy values in 2003 and 2017

Urban Area	Entropy 2003	Entropy 2017	Percent change	Sprawl Indicator
Nablus	0.920	0.954	3.7%	+
Qalqilya	0.882	0.947	7.4%	+
Bethlehem	0.892	0.934	4.8%	+
Hebron	0.904	0.924	2.2%	+
Tulkarem	0.881	0.918	4.3%	+
Ramallah	0.870	0.898	3.2%	+
Jenin	0.820	0.866	5.7%	+
Tubas	0.839	0.864	3.0%	+
Salfit	0.843	0.846	0.4%	+
Jericho	0.741	0.813	9.7%	+

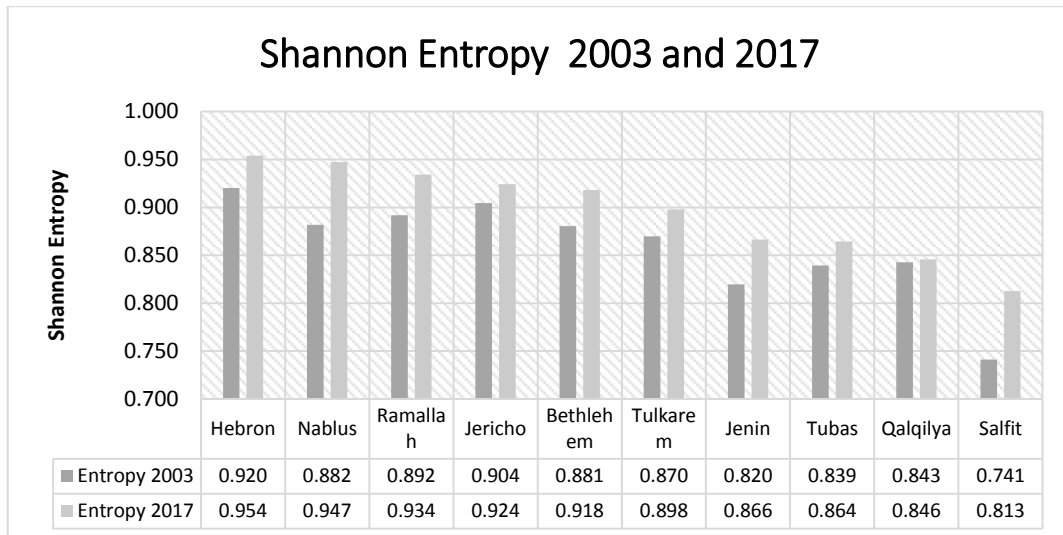


Figure 39: Shannon entropy values in 2003 and 2017

- **Discussion**

Shannon entropy is a measure of disorder in a system (spread, chaos). Low values of entropy indicate a more concentrated built up area across the landscape while high entropy mean that the system is more spread out. Since urban sprawl is a dynamic process and a part of a system that continuously changing, urban area configuration can change as time passes. Hence, the change in entropy between two time points can be used to evaluate if sprawl has increased or decreased in the urban area.

The results of the measure suggest the following :

- The results of all urban area are closer to 1 (ranges between .8 and .9) implying a high dispersion of built up area across the study area (buffers of the analysis) or in other words: **the built-up area is evenly dispersed among the study area .**

- All urban areas have increased in their entropy values from 2003 to 2017 indicating an increase in urban sprawl in all of these areas.
- The highest entropy value in 2017 is observed in Nablus, followed by Qalqilya, and Bethlehem indicating a high even distribution of their built-up areas across the study area
- The lowest entropy values are found in Jericho, Salfit, and Tubas , meaning that their built- up area is less evenly distributed across the study area
- The highest change in entropy values is observed in Jericho , meaning that Jericho is the most urban area going towards sprawl in its development, whereas, the lowest change value was observed in Salfit.

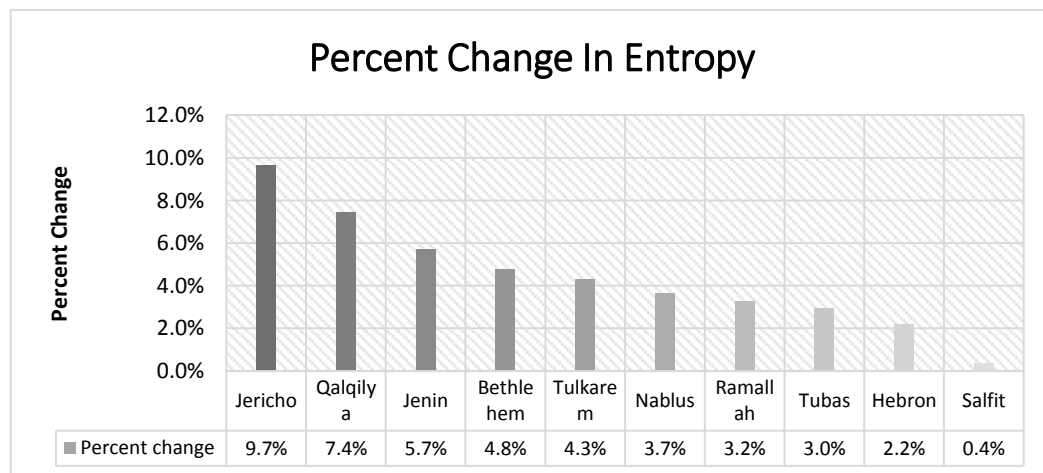


Figure 40: Percent change in entropy values

Although this measure is the most widely used by urban planners in studying sprawl , the personal efforts made in this research have found that the value of the measure is sensitive to number and the shape of buffer zones (same as the spatial statistics problem of modifiable areal unit) . This

was investigated by calculating the entropy using four different methods. This result is contradicted with the fact that entropy is widely accepted as the less scale sensitive sprawl measure . The following table explains the differences in entropy values , one with using the circular buffers, and the other with using grid tiles zones with both the built-up area and the buildings area. The selected method for this research is built up area with buffer zones (same as the majority of the previous studies).

Table 39: The differences in Shannon entropy values according to type of buffers

Shannon entropy values								
Value of P DENi	Buffer (circular)				Grid			
	built up area/zone area		buildings area/zone area		built up area /unit area		buildings area /unit area	
Urban Area	2003	2017	2003	2017	2003	2017	2003	2017
Jenin	0.7902	0.8675	0.47	0.56	0.91	0.92	0.87	0.86
Tulkarem	0.8071	0.8627	0.56	0.59	0.93	0.95	0.90	0.90
Nablus	0.7626	0.8255	0.62	0.71	0.94	0.96	0.90	0.93
Tubas	0.7532	0.7897	0.35	0.40	0.89	0.88	0.80	0.77
Qalqilya	0.6979	0.7706	0.52	0.59	0.93	0.95	0.88	0.87
Salfit	0.7350	0.7642	0.40	0.45	0.91	0.89	0.84	0.83
Ramallah	0.6404	0.7322	0.64	0.65	0.94	0.94	0.92	0.92
Bethlehem	0.6119	0.5994	0.70	0.71	0.93	0.95	0.91	0.91
Hebron	0.5416	0.5992	0.71	0.72	0.95	0.95	0.91	0.91
Jericho	0.4037	0.5386	0.45	0.49	0.92	0.91	0.87	0.88

- **Ranking**

As a pattern (worst to best)

Table 40: Ranking the urban areas according to Shannon entropy values in 2017 from the highest to lowest sprawl

Urban Area	Nablus	Qalqilya	Bethlehem	Hebron	Tulkarem	Ramallah	Jenin	Tubas	Salfit	Jericho
Entropy 2017	0.954	0.947	0.934	0.924	0.918	0.898	0.866	0.864	0.846	0.813

As a process (worst to best)

Table 41: Ranking urban areas according to change in entropy values between 2003 and 2017 from the most to least changing

Urban Area	Jericho	Qalqilya	Jenin	Bethlehem	Tulkarem	Nablus	Ramallah	Tubas	Hebron	Salfit
Percent change	9.7%	7.4%	5.7%	4.8%	4.3%	3.7%	3.2%	3.0%	2.2%	0.4%

4.2 Overall Ranking

4.2.1 Ranking strategy

Urban areas were ranked based on 3 types of ranking , first, the ammount of sprawl parameters that an urban area qualify as sprawl . The second type of ranking is based on the pattern of sprawl according to sprawl indicators values in 2017. The third and the final ranking is based on the process of sprawl, in which urban areas are ranked from the most changing to least changing towards sprawl between 2003 and 2017. All of the three rankings are -as discussed earelier in this thesis- based on relative sprawl, implying

that there is no defined threshold, or a black and white distinction that recognize sprawling development from non-sprawling development. Instead, urban areas are set on a continuum, from the relatively most sprawling to the relatively least sprawling. The overall ranking was finally computed by adding the marks of each type of rankings for each urban area in order to sort them from the most to least sprawling. Ranking procedure and tables are presented in appendix 4.

4.2.2 Ranking Results

- According to number of sprawl indicators (out of 10)

Table 42: Ranking of urban areas according to the number of parameters indicating sprawl (worst to best)

Urban Area	Jenin	Tubas	Jericho	Hebron	Qalqilya	Bethlehem	Nablus	Ramallah	Tulkarem	Salfit
Number of sprawl indicators /10	9	9	9	8	8	7	7	7	6	5

- According to pattern of sprawl in 2017 (out of 100)

Table 33: Ranking of urban areas according to sprawl parameter values in 2017 (worst to best, left to right)

Urban Area	Hebron	Nablus	Jericho	Jenin	Tulkarem	Bethlehem	Ramallah	Tubas	Qalqilya	Salfit
Sprawl as a pattern /100	74	70	69	61	61	60	58	57	26	22

- According to process of sprawl (from the most changing to least changing towards sprawl) (out of 100)

Table 44: Ranking of urban areas from the most changing to least changing toward sprawl (left to right)

Urban Area	Jericho	Jenin	Tubas	Qalqilya	Hebron	Tulkarem	Nablus	Salfit	Bethlehem	Ramallah
Sprawling process/100	73	73	73	59	55	48	46	43	41	39

- Overall ranking of sprawl

Table 45: Ranking urban areas according to their overall value of sprawl from the highest to lowest

Urban Area	Jericho	Jenin	Tubas	Hebron	Nablus	Tulkarem	Bethlehem	Ramallah	Qalqilya	Salfit
Overall sprawling value/210	151	143	139	137	123	115	108	104	93	70
sprawling percentage (293=100%)	72%	68%	66%	65%	59%	55%	51%	50%	44%	33%

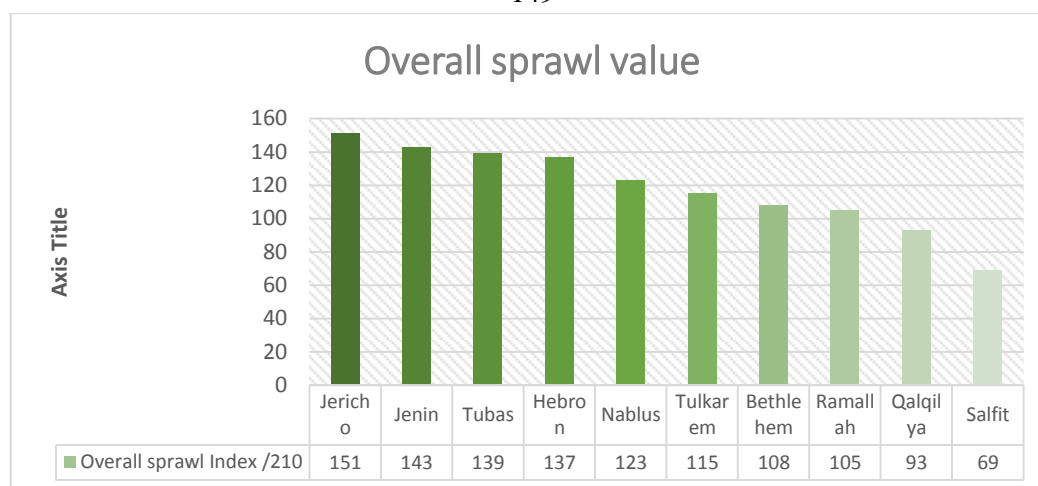


Figure 41: Ranking urban areas according to their final overall sprawl value from worst to best (left to right)

4.3 Summary

We can draw the following conclusions from the final tables :

- All urban areas have qualified sprawl indicators during their growth between 2003 and 2017 , but with different percentages . This result ensures our hypothesis and the question of whether urban areas have witnessed sprawling development pattern during the study period or not .
- The evaluation of the pattern of sprawl in 2017, which was mainly based on three pattern components: growth , density and urban form , explains the extent of sprawl and provide for a comparable results among each urban area. Examination of the pattern has showed that Palestinian urban areas are generally marked with high densities, contagious urban forms and strong urban structure.

- The process of sprawl , revealed by quantifying the difference in sprawl indicators values indicates that all urban areas have changed towards sprawl through their developmnet between 2003 and 2017. This is evident through the increase in sprawl indicators values through the study period . The amount of change in these values are used to rank the urban areas from the most changing to the least changing towards sprawl .
- The total evaluation of sprawl was calculated by adding the values of each of the previous rankings , and gives an overveiw on the overall status of sprawl in each urban area. Jericho, Jenin, and Tubas has recorded the highest sprawl among the other urban areas and marked as the most sprawling areas in West Bank.

Chapter Five

Conclusion and Recommendations

5.1 Introduction

The main purpose of this study was to analyze the spatial development patterns of the Palestinian communities in WB and assess their change from 2003 to 2017 to determine if these areas are going towards sprawl in their development or not. The urban spatial analysis of the Palestinian communities gains its importance from the unique geopolitical situation that affected the spatial development of these communities for many decades. This political conflict over land is represented in the geographic siege and the tight boundaries for urban spatial growth, which has contributed to create discontinuity among these areas. Further complicating the issue is the current planning system which is a mixture of all the different planning practises of the several political regimes that have dominated the area for many years.

Our survey has found a lack in studies addressing the spatial dimension of urban sprawl, knowing that many scholars have referred to the spatial development patterns of Palestinian communities as sprawling based on subjective judgments and without supporting their claims by empirical evidences . The main contribution of this research was to enrich the Palestinian literature with in-depth knowledge about sprawl, and to design a method for empirical analysis, in order to objectively characterize

the current patterns based on the quantitative results of the spatial indicators of sprawl.

The approach of the research has proven its efficiency in characterizing the multiple patterns of sprawl by using a set of parameters rather than using a single characterization method. However, the analysis illuminated a number of issues that must be adequately addressed in future research of sprawl in Palestine. Characterizing urban sprawl within the Palestinian context puts forward some controversial questions that still needs in-depth answers. Sprawl is internationally characterized by low density development pattern. Based on this, and within the current geopolitical de facto of the Palestinian development, marked by an alarming density levels and stretched carrying capacity; Can in-fill development be considered as a remedy for sprawl? Should we continue expanding in the urban outskirts with an unplanned manner, in the light of structural plans deficiency, vacant land scarcity, and the absence of PA jurisdiction over area C? These questions and many others, imposed by the unique Palestinian realities, are subjected to further debate, and needs to be carefully and meaningfully answered by experts and planner.

5.2 Conclusion

In this research, the pattern and the processes of urban sprawl for the Palestinian urban areas were analysed using a set of spatial sprawl indicators of density, urban growth, and urban form. The approach of this research analysed all of the three spatial dimensions to complement each

other in order to understand the complexity of the phenomena using a set of 10 spatial parameters. The decision of whether these parameters indicated sprawl or not was made by looking at change in parameter value from 2003 to 2017. The general outcome of the analysis implied that all urban areas have qualified sprawl during their growth between 2003 and 2017 with different magnitudes and percentages. The main outcome answers the main research question of whether the palestinian areas witnessed sprawl in their development between 2003 and 2017 or not. The specific conclusion of each sprawl dimension and research questions can be summarized as follows:

5.2.1 Density

Density analysis has allowed us to analyse if the new development areas had a relatively lower density than redeveloped areas, to assess the relationship between density and distance from the main urban center, and to compare the different urban areas for their process of sprawl. The main findings of the density analysis reflected a falling tendency of the density gradient curve from 2003 to 2017 and over distance from the center for all urban areas with different percentages, implying a sprawling trend of the new development that is manifested in suburban lower than average density development. This flattening can be a result of suburbanization processes and reflects the tendency towards sprawl. The analysis has also concluded that densities were all higher in 2017 than in 2003. The results have also emphasised the negative relationship between density of the new development and distance from the main urban center.

5.2.2 Urban growth

Urban growth, which is the second spatial dimension of sprawl, was quantified by calculating growth rates of population and builtup area, and growth patterns. The results of the analysis indicated that builtup area growth rates exceeded population growth rates for the majority of the study areas (8 out of 10), thus, reflected the tendency for the new development areas towards being more sprawling with time. This result is very compatible with the density analysis which has revealed that all urban areas has relatively lower densities in their urban fringes, reflected by the flattening tendency of the density curve over time. However, these percentages were varying and distinct . This variation might be attributed to the amount of the politically available land for development and other factors.

The examination of growth patterns occurring in the urban areas has allowed us to understand the types and the direction of new growth areas. The analysis implied that these areas haven't followed an exact pattern. Some areas had their infill growth percentages higher than extension or outlying growth. However, the majority of these areas (7 out of 10) had more extension than in fill or outlying growth.

5.2.3 Urban form

The third and the final dimension of sprawl concerns the spatial geometry of the urban form has allowed us to examine the degree of complexity and fragmentation of new growth areas and was

complementary to density analysis. The more fragmented and complex the builtup area with time, the more sprawling the pattern. This analysis found a varying nature of growth among the urban areas. There is no specific development trend dominating all urban areas at the same time, and this may be due to the uniqueness of their surrounding geographic circumstances.

By looking at the values of complexity measures, one can notice that Palestinian urban forms are generally closer to simpler rather than complex geometries. However, the change from 2003 to 2017 has reflected a relative decrease in urban form simplicity for the majority of the urban areas, except for certain cities which their forms became less complex and more compact with time such as Qalqilya and Salfit.

The group of fragmentation measures assess different aspects of urban form including size, number, distance, and distribution of urban area. Same as complexity measures, one can notice that these values generally indicate well-structured and monocentric urban forms, and this is compatible with the highly dense nature of Palestinian urban settlements. However, the change in urban structure from 2003 to 2017 is, on the one hand, marked by a general increase in contiguity and consolidation of the main builtup area as a result of urban expansion in a limited area; and on the other hand, a general increase in scatter, patchiness, and entropy values as a result of the new outlying and scattered development, especially in the non-politically besieged urban area, thus indicating a sprawling attitude dominating the development in this era.

The overall results of the analysis are compatible with each other. Examination of the pattern has showed that Palestinian urban areas are generally marked with high densities, contagious urban forms and strong urban structure, however, examination of the process of change from 2003 to 2017 has revealed that the dominating trend in the growth of these communities is marked by urban sprawl, thus, a careful and meaningful planning is needed to eliminate this phenomenon.

5.2.4 An initial definition of the Palestinian sprawl

One of the goals of this study was to draw an enhanced definition of sprawl within the Palestinian context due to absence of clear knowledge on sprawl definition within the existing literature. Based on the empirical results of our analysis, and by making use of previous sprawl research in Palestine (Dawwas,2011; Abu helu,2012 and others) Urban sprawl in Palestine can be defined as follows:

“Unplanned, uncontrolled growth, characterized by irregular and complex spatial patterns, shaped by the geopolitical situation, aggravated by the planning deficiencies, and have an agricultural encroachment character”.

5.3 Recommendations

The urban development of Palestinian communities is marked by high rates of population growth (UN, 215; PCBS, 2016) and high levels of urbanization, thus making urban expansion all but inevitable to encompass

the future needs of population. However, this need for expansion is associated with land scarcity due to the unstable geopolitics of the area.

The outcome of the research has generally indicated a sprawling tendency of the Palestinian urban areas during the study period that is represented in many ways; for example: built-up area growth rates outpaced population growth rates for many cities during the study period indicating a higher consumption of lands per capita and lower densities at urban fringes. This trend has also been insured by density gradient analysis which showed a falling tendency during the study period. Furthermore, the increase in fragmentation and complexity of urban fabric for many urban areas was evident. Based on this outcome, the research generally recommends the elimination of sprawl as a general policy to be adopted by planners and decision makers to avoid its negative consequences.

The research recommends the following with regards to each analyzed sprawl dimension:

5.3.1 Density dimension

The density gradient analysis has reflected the falling tendency of the gradient value through the study period for all urban areas. This decrease is a result of a decentralization process and indicates lower degrees of nuclearity for urban areas thus a less centralized urban structure overall. From a planning perspective, the less centralized urban structure is something to avoid for the overall accessibility and economic efficiency.

Based on this, the research recommends planners to focus on zoning activities to allocate future development and comprehensive planning that accounts for future population needs to avoid unplanned and outlying patterns of growth. Sub urbanization refers to many reasons, one of them is the disability of population to afford housing inside the official masterplan boundaries. This can be solved by enhancing the role of government in financial support of public housing.

Another approach that might be adopted by planners is the (planned suburbanization) of jobs, homes, and services all together at a proximity of the main urban center. The advantages of this strategy include reducing the pressure on the main center on the one hand and enhance the situation of the surrounding rural areas on the other. The suburbanization of jobs and homes together will reduce traffic congestion and guarantee more accessibility. This is also known as an economically efficient leapfrog development in economic theory, if done properly. Another added value is the better infrastructure and services that residents of the new areas gain since it will be previously planned.

5.3.2 Urban growth dimension

Urban growth pattern analysis has revealed that population growth rates exceeded builtup area growth rates for most of the urban areas under analysis. This result is compatible with the density analysis and indicates lower than average densities at urban fringes and more land consumption per capita. Based on this, the research recommends balanced urban

developments were the amount of consumed land for development reflects the real needs of populations increase. The pattern analysis has also found a considerable amount of outlying growth especially in eastern part of WB. The outlying pattern of growth must be contained.

Within this context, and as discussed earlier in literature, it's important to distinguish urban sprawl (which stands for unplanned and consumptive pattern of growth) from other types of growth such as regulated or planned urban expansion.

The research doesn't however encourage urban infill as a remedy of sprawl as adopted by industrialized countries (the compact city theory). In developing countries, compactness or "densification" through in-fill development is not desirable since they already have densities three times higher than developed countries (Angel et al., 2005). In Palestine as well, central densities are very high (80% plot coverage) (Helu, 2012). This high density is associated with infrastructure overload, overcrowding and congestion, lack of public and green space, and environmental degradation. Within this context, the research recommends planned outward expansion in the periphery of the current buildup areas with two conditions: first, this expansion should not exceed population needs, have a reasonable density, to be planned and zoned by municipalities, and to accommodate for future needs of population. For areas that has no spaces left for horizontal expansion such as Qalqilya, the research recommends wise use of space by adopting vertical development strategy and apartment system in vacant

spaces in order to accommodate more residents, and accounts for the need of public space, ventilation and minimum setbacks for buildings.

5.3.3 Urban form dimension

The analysis showed that urban forms of Palestinian cities are closer to simple geometries, well structured, and monocentric. However, this simplicity has decreased for all areas, and fragmentation indices increased from 2003 to 2017. This increase in complexity and fragmentation is one of the multiple forms that urban sprawl can take and can be attributed to scattered and outlying patches of development. This research suggests outskirts infilling strategy at urban fringes of Palestinian communities, with ensuring an accepted compactness level. In turn, this will decrease urban form complexity, reduces fragmentation and increase accessibility.

The research then reassures the role of planning in limiting urban sprawl and maintaining a healthy and well-organized growth that is regulated by zoning and planning subdivisions. This comprehensive planning should consider a long-term vision with regards to absorption capacity, accessibility, and balanced urban and rural development. The long-term vision plays an important role in planning for Palestinian cities, since population increase is high, land resources are limited, and development processes are irreversible, thus requiring the pre-knowledge of all possible scenarios for future. The preparation for this plan should be preceded by dense suitability analysis studies on where this expansion would be most easily accommodated, how infrastructure would be served,

and how can this be done with minor environmental impacts and insure economic efficiency.

The research also suggests a comprehensive recovery plan for currently developed areas by municipalities through the approach of urban design in order to enhance the current city image, rehabilitate the green public spaces, invest in provision of roads and sidewalks, and provide parking areas. This will in turn encourage people to stay in city rather than fleeing away by personal preferences and contribute to unplanned suburbanization.

The research also recommends the following actions to enhance the role of planning in eliminating urban sprawl:

- Filling the data shortage by building a strong database from current and archived data to model the predicted future change and adequately prepare for it.
- It is recommended that the strategic plans preparation should be more realistic and involve a wider variety of stake holders including private and public institutions, planners, individuals, landowners, and academics.
- The financial support for scientific planning research should take apart. This research should include urban growth simulation studies, suitability analysis studies, bearing capacity of the central areas, accessibility studies, and many others.

- Coordination between planning institutions on the different national, regional, and local levels.
- Adopting a policy of Protecting green and agricultural lands
- And finally, the balance between cities with each other on the one hand, and between cities and villages in development projects on the other hand.

5.4 Future research

This study is still at its initial stages. Further studies should be made in order to enrich the literature on urban sprawl, and to understand the phenomenon more precisely. Urban sprawl has many dimensions and scales of study to be fully understood. This study has only focused on the spatial dimension of the phenomenon on one scale. However, the shortage in data has obstructed further research.

The absence of archived land use data in 2003 for Palestinian cities has prohibited this research to include the land use dimension of sprawl. Further studies are suggested to analyse this dimension of sprawl for Palestinian cities for a single year. Urban sprawl is defined by a poor land use mix of jobs, housing and services. All of the previous models can be applied on the land use parcel type instead of the total built-up area to understand the urban fabric complexity or heterogeneity levels, which will contribute to understand other important indicators such as accessibility, land use mix, and proximity.

The research also suggests taking advantage of spatial statistics of GIS. These tools deal with spatially referenced data and able to categorize these data for a spatially homogeneous clusters depending on their attribute values and provide as a useful measure of urban sprawl. This study was not able to use these tools since it has also lacked the attribute data associated with buildings for the analysis.

The research also suggests including the vertical density instead of using only footprint density to gain more precise density analyses results. This requires the use of number of residents per building, which was also not available for this study.

Finally, this study suggests further similar studies to be conducted on the governorate level and compare the city sprawl with rural sprawl.

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Appendix 1

Collected literature on urban sprawl

Table 1: Common urban sprawl definitions (Source: Author)

Resource	Definition
Altshuler and Gomez- Ibanez (1993)	“continuous low-density development of urban fringe, low-density development along main high-way of suburb”
Nelson and Duncan (1995)	“...unplanned, uncontrolled, and uncoordinated single use development that does not provide for a functional mix of uses ...variously appears as low-density, ribbon or strip, scattered, leapfrog, or isolated development.”
Burgess and Thomas (1997)	“Sprawl defined as expanding physical development, at decreasing densities, in metropolitan regions, where the spatial growth exceeds population growth.”
The Sierra Club (1998)	“low-density development beyond the edge of service and employment, which separates where people live from where they work and therefore requiring cars.”
Torrens and Alberti (2000)	“Sprawl is a relatively wasteful method of urbanization, characterized by uniform low densities. It is often uncoordinated and extends along the fringes of metropolitan areas with incredible speed.”
Galester (2001)	“an urbanized area exhibiting low levels of eight distinct dimensions of land use pattern: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity”
Ewing (2002)	“The landscape sprawl creates has four dimensions: a population that is widely dispersed in low density development; rigidly separated homes, shops, and workplaces; a network of roads marked by huge blocks and poor access; and a lack of well-defined, thriving activity centres.”
Hasse (2002)	“Urban sprawl is wasteful, inefficient and or dysfunctional urban growth within the context of a landscape.”
Wassmer (2002)	“In one sense, urban sprawl is just another phrase for “excessive” metropolitan decentralization or Suburbanization.”
Burchell and Galley (2003)	“Sprawl is low-density, leapfrog development characterized by unlimited outward extension.”
Wilson et al. (2003)	“Urban sprawl,” the land-consumptive pattern of suburban development.”
Wassmer (2005)	“Sprawl from land use perspective such as the degree of compactness did not generate statistically significant results.”
Sudhira and Ramachandra (2007)	“Urban sprawl refers to the outgrowth of urban areas caused by uncontrolled, uncoordinated and unplanned growth. This outgrowth seen along the periphery of cities, along highways, and along roads connecting a city, lacks basic amenities like sanitation, treated water supply, primary health centre, etc.”
Bhatta (2010)	“the less compact outgrowth of a core urban area exceeding the population growth rate and having a refusal character or impact on sustainability of environment and human”

Table 2: Summary of international empirical previous studies of urban sprawl (Source: Author)

Resource	Dimension	Indicators	Parameters		
Frenkel et al. 2016	Process	Growth rates	Change in total amount of urban land cover Growth in residential area Growth in low-density residential area Amount of and change in availability of developable land		
	Density	Density	gross population density, net population density, current and expected population divided by developed and developable land, density as a function of accessibility to the CBD, density gradients, and amount of population living in low density		
	pattern	Spatial Geometry	<i>composition</i>	leapfrog, connectivity, the number of patches, Mean patch size, contagion, connectance, proximity and contagion	
			<i>configuration</i>	Edge shape (e.g. circularity) Area to circumference ratio Continuity indices (applied primarily to open space) Leapfrog indices (applied primarily to built space). Equal to % built in urban core / % built outside urban core. Fractal dimension	
	Land use	Accessibility	Road length/area Household traveling time Mean Proximity Index Gravity/logit models		
	Aesthetic	Aesthetic measures	standard deviation photogrammetric approaches		
Torrens and Alberti 2000	Density Or form	Density density gradients.	quadratic gamma functions equilibrium function		
		Surface of sprawl	kernel density		
	Aesthetic	Architectural configuration	architectonical and photogrammetric approaches standard deviation		
	pattern	The fractal dimensions	fractal dimension index (extent to which a city fills its two-dimensional area)		
		geometry of scatter	weighed mean distances (degree of isolation of developed lands) fragmented, leapfrogging, discontinuous, dispersal, or piecemeal		
		Ecology	<i>composition</i>	Shannon's diversity, evenness Index	
	<i>configuration</i>		patch density mean patch size,		

			contagion, interspersion and juxtaposition, and proximity
	pattern	accessibility	opportunity-based measures utility-based measures
Angel et al. 2007	Density	Density	Built-up area density, urbanized area density, urbanized area density restricted to developable area, urban foot print density, and urban footprint density restricted to developable area
	pattern	Urban extent	Built up area, urbanized area, urbanized open space, developable open space, urban foot print, open space and peripheral open space.
		Suburbanization	Cohesion, decentralization, city center shift, minimum average distance center and density gradient.
		Contiguity and openness	New development, new infill development, new extension development, new leapfrog development, openness index, open space contiguity and open space fragmentation.
	Compactness	Single point compactness and constrained single point compactness.	
Jiang 2007	pattern	Spatial geometry	area index, shape index, discontinuous development index, stripe development index, leapfrog development index,
	causes	Consistency with urban plans	planning consistency index,
	Density	Density	horizontal density index, vertical density index, population density index, GDP density index,
	Impact	Environmental resource impact	agricultural impact index, open space impact index and traffic impact index.
Sudhira and Ramachandra 2004	Process	Population growth	rate of built up area growth VS the rate of population growth
	Urban form	landscape pattern	Shannon entropy Patchiness Map density
	causes	causal factors	Population, population density, annual population growth rate, distance from Mangalore, distance from Udupi.
Gar-OnYeh et al. (2001)	Urban form	landscape pattern	Shannon entropy
Yu and Ng (2007)	Urban form	landscape metrics	gradient analysis
Seto and Fragkias	Urban form	spatial metrics	edge density, total urban area, urban patch count, mean patch fractal dimension, average

(2005)			patch size, and patch size coefficient of variation
world bank 2005	Urban form	urban extent and expansion urban spatial structure	Built up area, Density contiguity index compactness openness index
Galester et al 2001	pattern	Land use pattern	: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, proximity
Ewing et. al, 2002	density	Residential density	Gross population density, suburban density, urban density, density at center of a metropolitan area, gross population density of urban lands, lot size, and population center density
	pattern	Neighbourhood mix of homes, jobs and services	Percent of residents with businesses or institutions within ½ a block of their homes, percent of residents with “satisfactory” neighbourhood shopping within one mile, percent of residents with a public elementary school within one mile, balance of jobs to residents, balance of population-serving jobs to residents, and mix of population-serving jobs.
		Strength of activity centers	Coefficient of variation of population density across census tracts, the rate of decline in density from the CBD (density gradient), percent of population that lives less within 3 miles of the CBD , percent of population that lives more than 10 miles from the CBD, percent of population relating to centers within the same metropolitan area, and ratio of density between the highest density portion of the metropolitan area and the entire metropolitan area
		Accessibility of street network	Average block length in the urbanized portion of the metro area, average block size in square miles (excluding blocks greater than one square mile), and percent of small blocks.
Hasse 2004	pattern	land use patterns	Low land use density index, leapfrog development index (a measure of continuity), segregated land use development index (a measure of the degree of the land use mix at pedestrian scale), development that is inconsistent with regional planning index, and Highway strip development index.
		Transportation infrastructure	New road infrastructure inefficiency index, inaccessibility to alternate modes of transportation, community node inaccessibility
	Impact	Environmental resource impact	Loss of important land resources, encroachment upon sensitive, preserved open space; excessive per capita impervious surface coverage; and explosive growth trajectory imposed on localities by new development.

Table 3: summary of previous local urban sprawl studies (Palestine)
(Source: Author)

<i>Study</i>	Objectives	Methods	Study area
Salem Thawaba (2011) Multi criteria analysis for locating sustainable suburban centers: A case study from Ramallah Governorate, Palestine (working paper)	locate the most sustainable sites for future development to avoid unplanned sprawl	Multi Criteria Analysis using GIS	Ramallah
Ahmad Al-Noubani (2009) Land use/ land cover dynamics: a case study from Palestinian West Bank (doctoral research)	<ul style="list-style-type: none"> • Investigate dynamics , patterns and spatial distribution of Land use/Land Cover change in WB and the process of sprawl over a nine years' time period (1994-2003) • Model significant drivers of change to predict the spatial patterns in near future 	<ul style="list-style-type: none"> • Remote sensing techniques • Logistic modelling 	West Bank
Musallam F. Abu Helu (2012) Urban sprawl in Palestinian occupied territories (working paper)	<ul style="list-style-type: none"> • Understand the overlooked magnitude of sprawl in Palestine by exploring conditions that makes planning focus more on sprawl rather than security • Address the forces that created sprawl • Discuss its negative impacts • Suggest alternative approaches to address population needs while limiting sprawl 	Descriptive Historical approach	Palestine
Mohammad Muhsen (2016) Urban transformations in the West Bank of Palestine, drivers and consequences : a case of Ramallah area (doctoral research)	<ul style="list-style-type: none"> • Investigate the role of geopolitics and socio-economics that prompted internal migrations to Ramallah • Analyse the major spatio temporal trends and characteristics of urban expansion in Ramallah between 1997 and 2015 • Investigate consequences of transformation process • Create a model for near future scenarios 	Mixed methods <ul style="list-style-type: none"> • Descriptive historical approach • Spatio-temporal analysis using GIS and sprawl and growth indicators 	Ramallah
Ruba Soboh (2009) Sprawl areas and their Impact on the urban development of Palestinian cities (master thesis)	<ul style="list-style-type: none"> • clarify the patterns, types, and characteristics of informal housing in Palestine, • investigate the causes and impacts of these patterns 	<ul style="list-style-type: none"> • Qualitative descriptive , historical approach • Interviews • Case study approach 	Tulkarem, <i>Hai Al-Salam</i> Ramallah <i>Al-Ram</i>
Mohammad Kittaneh (2009) Study of urban	<ul style="list-style-type: none"> • Studying urban encroachment impact on agricultural lands • Investigate the causes of the current 	<ul style="list-style-type: none"> • Descriptive, historical approaches 	Ramallah

<p>encroachment impact on environment and agricultural land in Ramallah and Al-Bireh cities using Geographic Information Systems (GIS) and Remote Sensing (RS) techniques (master thesis)</p>	<p>trends of growth</p>	<ul style="list-style-type: none"> • GIS cartographic techniques • Remote Sensing 	
<p>Samer Raddad and Narimah Samat (2016) Urban development and expansion trends under the political instability in Palestine: Jerusalem- Ramallah case study (working paper)</p>	<p>Investigate urban expansion direction in Jerusalem – Ramallah within the geopolitical constrains</p>	<ul style="list-style-type: none"> • descriptive, • historical, • cartographic methods GIS digitizing and visual analysis 	<p>Ramallah and East Jerusalem</p>

Appendix 2

General Statistics on Built-up area and population of urban areas under study

Table 1: Builtup area statistics (Source: Author)

Urban Area	Built-up Area 2003 (km ²)	Built-up Area 2017 (km ²)	Increase in builtup area percentage
Jericho	5.53	12.46	125%
Tubas	2.49	4.89	96%
Nablus	13.24	23.63	78%
Jenin	6.83	11.51	69%
Tulkarem	8.87	14.62	65%
Hebron	28.22	44.33	57%
Bethlehem	13.43	19.00	41%
Qalqilya	3.57	4.95	39%
Salfit	2.30	3.07	33%
Ramallah and Albeireh	15.61	20.76	33%

Table 2: Population statistics (Source: Author)

Urban Area	Population 2003	Population 2017	Population Percentage change	Annual Growth Rate (%)
Jenin	34753	49908	44%	2.62%
Tulkarem	51750	72489	40%	2.44%
Tubas	14118	21431	52%	3.03%
Nablus	125060	173827	39%	2.38%
Qalqiliya	37676	51683	37%	2.28%
Jericho	17881	21792	22%	1.42%
Salfit	7949	10911	37%	2.29%
Ramallah and Albeireh	77399	115122	49%	2.88%
Bethlehem	73,132	97,012	33%	2.07%
Hebron	188,688	269,452	43%	2.58%

Table 3: Area C statistics (Source: Author)

Extended Urban Area	2003 total Built-up Area (km ²)	2017 total Built up Area (km ²)	2003 Built-up Area in area C (km ²)	2017 Built-up Area in area C (km ²)	Percentage of un-planned development 2003	Percentage of un-planned development 2017
Jericho	5.53	12.46	0.02	0.46	0.34%	3.69%
Tubas	2.49	4.89	0.01	0.03	0.20%	0.65%
Nablus	13.24	23.63	0.51	1.59	3.87%	6.74%
Jenin	6.83	11.51	0.02	0.45	0.32%	3.93%
Tulkarem	8.87	14.62	1.08	3.30	12.22%	22.55%
Hebron	28.22	44.33	2.55	6.44	9.05%	14.53%
Bethlehem	13.43	19.00	1.32	2.61	9.79%	13.75%
Qalqilya	3.57	4.95	0.34	1.27	9.65%	25.64%
Salfit	2.30	3.07	0.00	0.05	0.06%	1.76%
Ramallah	15.61	20.76	1.13	1.72	7.23%	8.28%

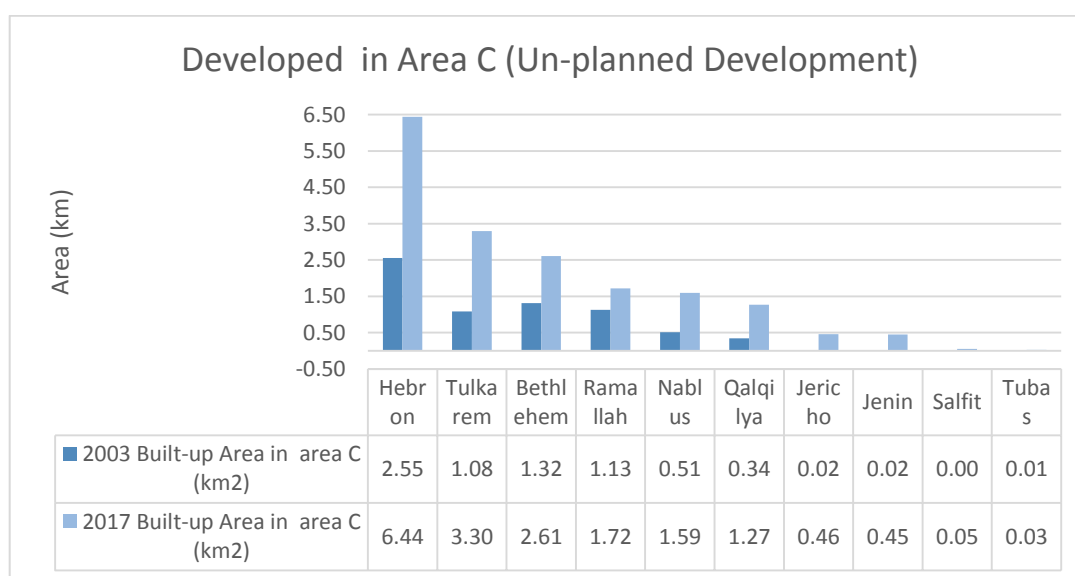
**Figure 142 : Builtup area over area C in 2003 and 2017 (Source: Author)**

Table 4: Remaining developable area in area (A and B) for each city in 2017 (Source: Author)

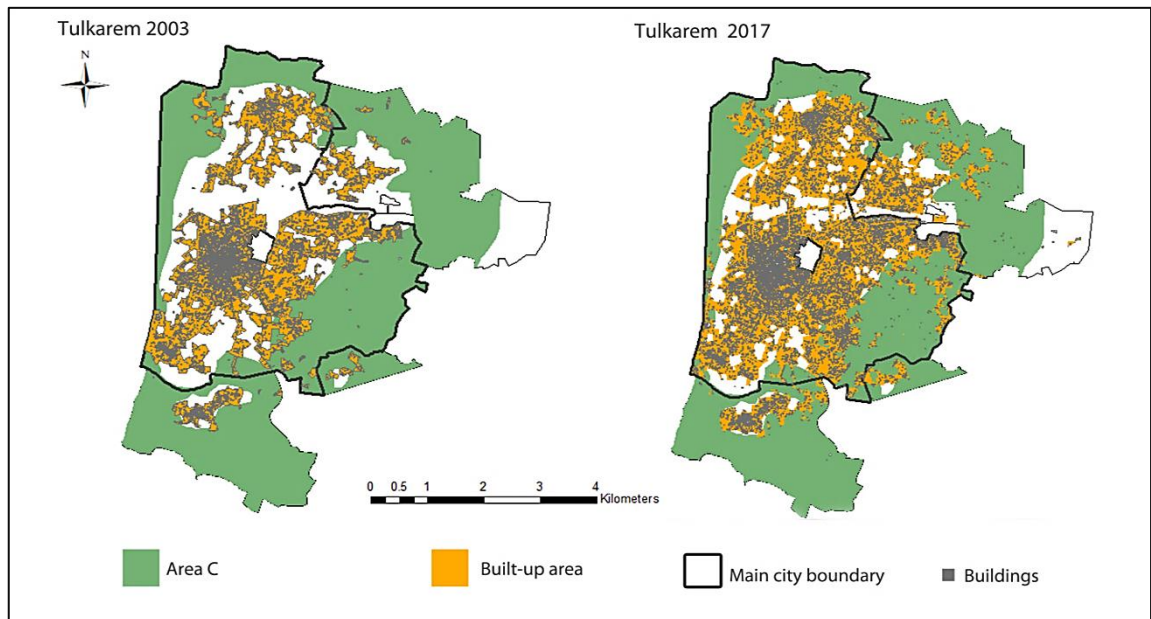
Main City	Administrative Area (km ²)	Built-up Area 2017 (km ²)	Area C Percentage of Administrative City Area (km ²)	Remaining Developable Area (In Area A&B) Post 2017 (km ²)
Jericho	172	11	80%	24
Tubas	223	5	84%	31
Nablus	32	19	20%	7
Jenin	39	12	24%	18
Tulkarem	20	12	41%	0
Hebron	46	29	28%	4
Bethlehem	11	5	45%	1
Qalqilya	10	5	63%	-1
Salfit	23	3	49%	9
Ramallah	38			

Appendix 3

City Data Sheets

This section summarizes all sprawl parameters values, attached with a change map for each urban area under study from 2003 to 2017.

Tulkarem

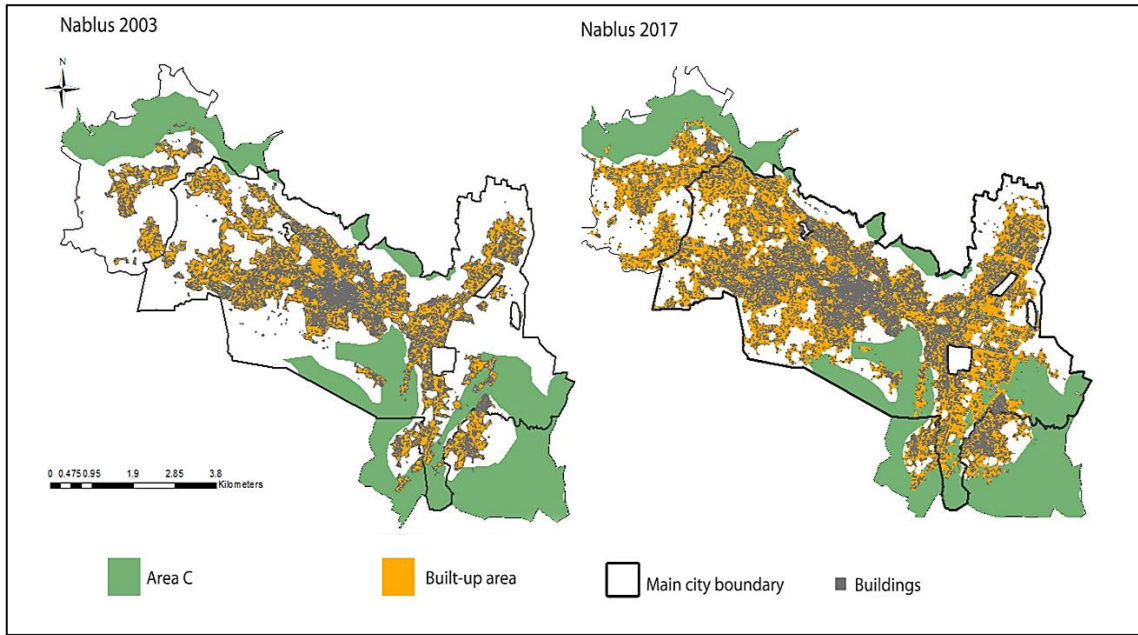


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00131	0.00099	-24.40%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		7%	85%	8%	2
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	Index	Sprawl indicator
		65%	40%	1.62	3

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity		Fractal Dimension	1.352	1.340	-0.89%
Shape Index			3.6	4.5	25.40%	4
Compactness			0.32	0.40	26.12%	
Configuration		Contiguity Index	0.66	0.94	42.12%	
		Patchiness	26	23	-11.54%	
		Scatter	1451	1664	15%	5
		Shannon Entropy	0.881	0.918	4.3%	6

Nablus

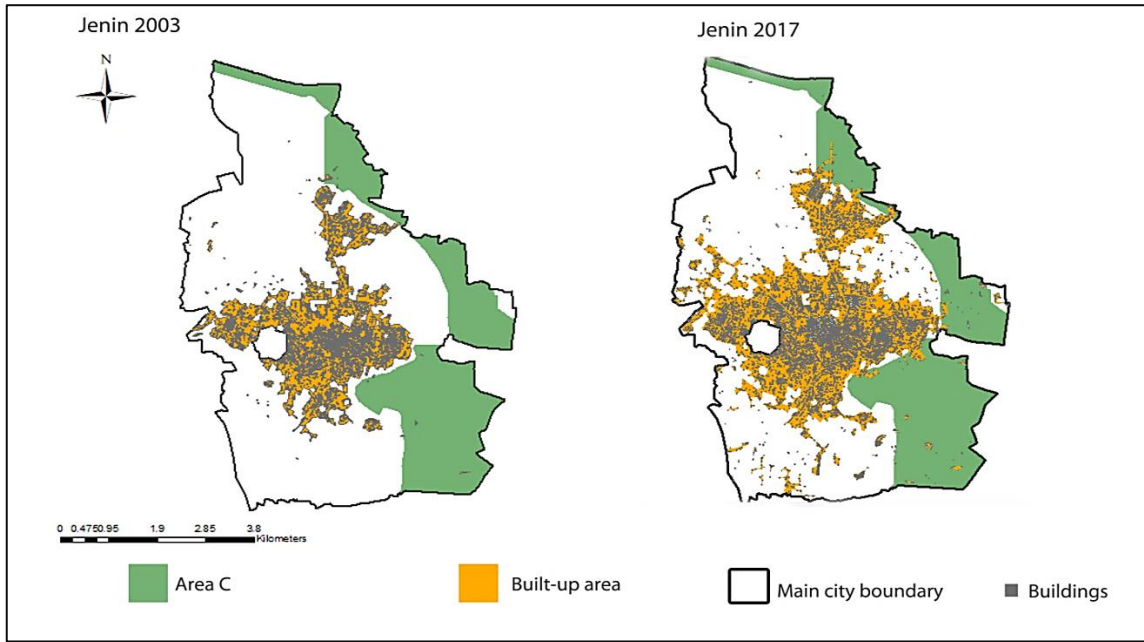


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00055	0.00045	-17.10%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
			44%	54%	2%
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
			78%	39%	2.01

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator	
	Complexity	Fractal Dimension		1.352	1.337	-1.09%	
		Shape Index		4.2	4.9	16.23%	4
		Compactness		0.23	0.23	0.08%	
	Configuration	Contiguity Index		0.76	0.98	29.20%	
		Patchiness		23	31	34.78%	5
		Scatter		2262	2530	12%	6
		Shannon Entropy		0.920	0.954	3.7%	7

Jenin

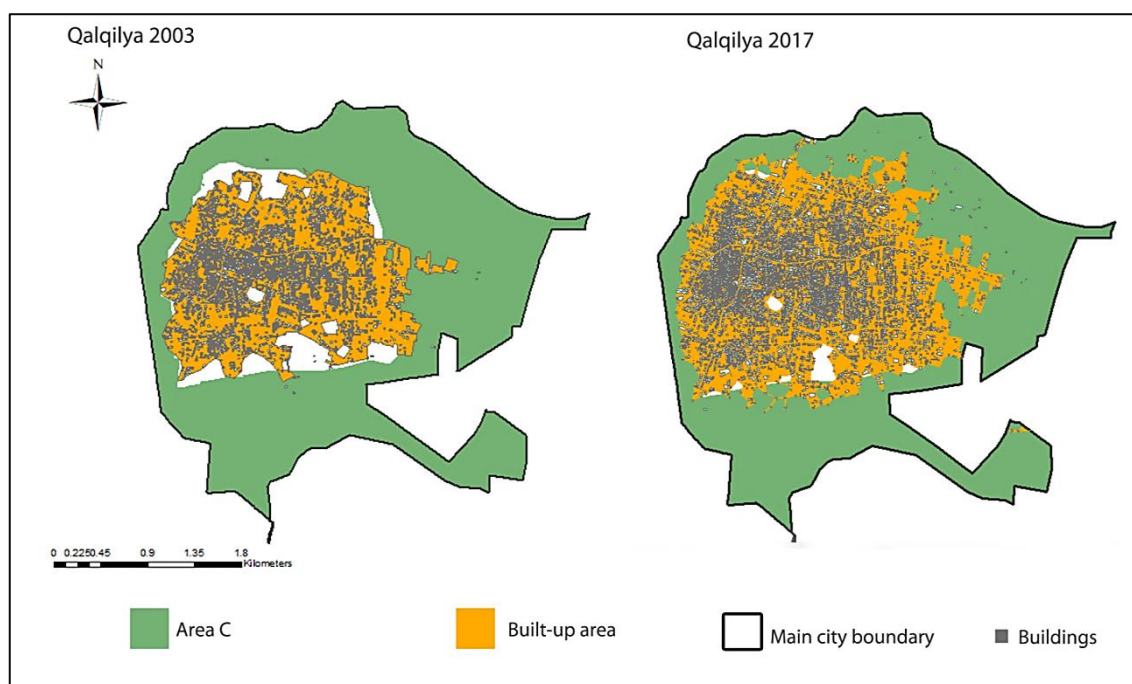


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00117	0.00093	-20.10%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		19%	67%	14%	2
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		69%	44%	1.57	3

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator	
	Complexity	Fractal Dimension		1.324	1.345	1.56%	4
		Shape Index		3.2	4.5	39.92%	5
		Compactness		0.31	0.29	-5.33%	6
	Configuration	Contiguity Index		0.84	0.95	13.52%	7
		Patchiness		18	43	138.8%	7
		Scatter		1170	1437	23%	8
		Shannon Entropy		0.820	0.866	5.7%	9

Qalqilya

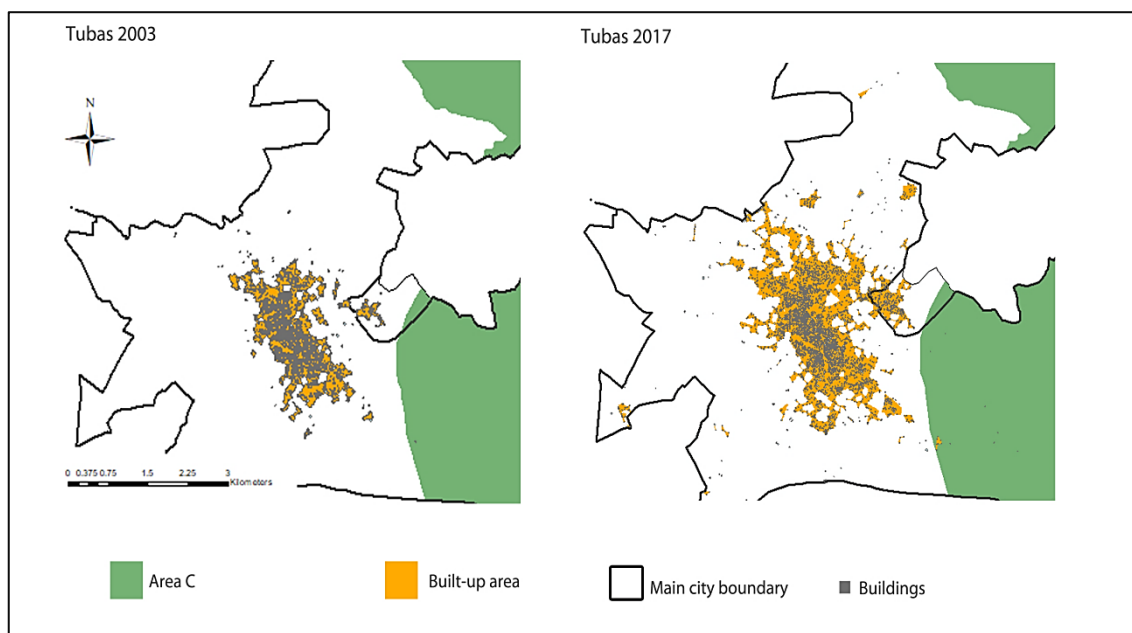


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00097	0.00082	-15.10%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		72%	27%	1%	1
	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		39%	37%	1.05	2

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity	Fractal Dimension	1.243	1.269	2.04%	3
		Shape Index	1.8	2.2	27.29%	4
		Compactness	0.64	0.58	-9.05%	5
	Configuration	Contiguity Index	0.99	1.00	0.91%	6
		Patchiness	2	3	50.00%	7
		Scatter	653	734	12%	8
		Shannon Entropy	0.882	0.947	7.4%	8

Tubas

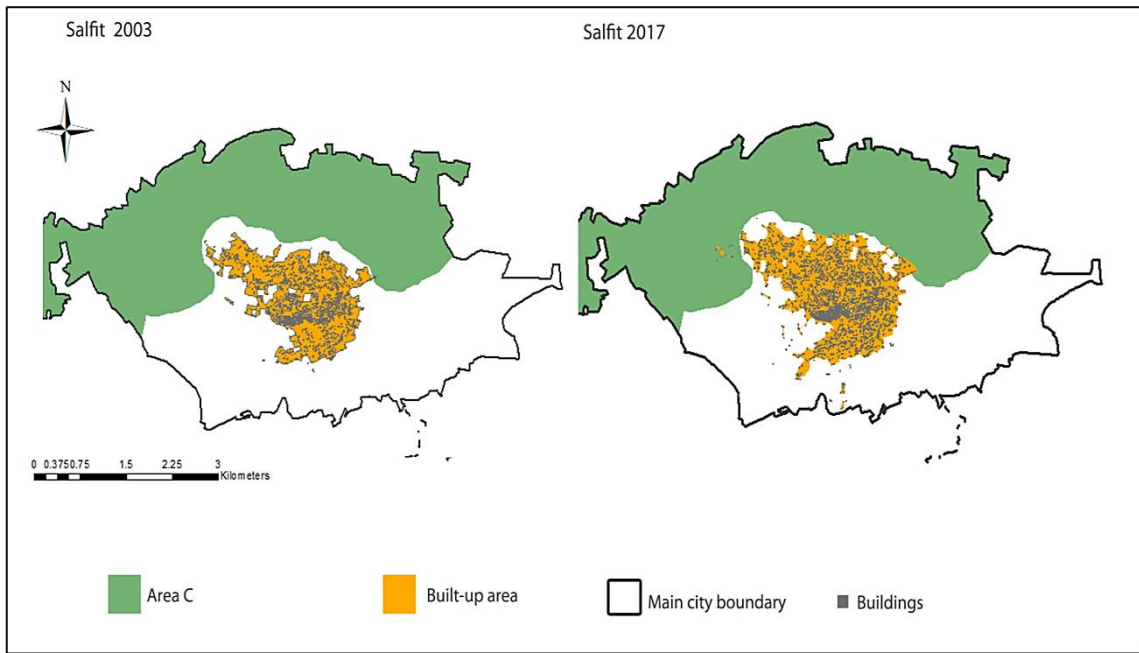


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00201	0.00163	-18.60%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		38%	46%	16%	2
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		96%	52%	1.86	3

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity	Fractal Dimension	1.334	1.352	1.35%	4
		Shape Index	3.1	4.0	28.40%	5
		Compactness	0.31	0.32	1.05%	6
	Configuration	Contiguity Index	0.91	0.91	-0.05%	6
		Patchiness	11	36	227.2%	7
		Scatter	735	1178	60%	8
		Shannon Entropy	0.839	0.864	3.0%	9

Salfit

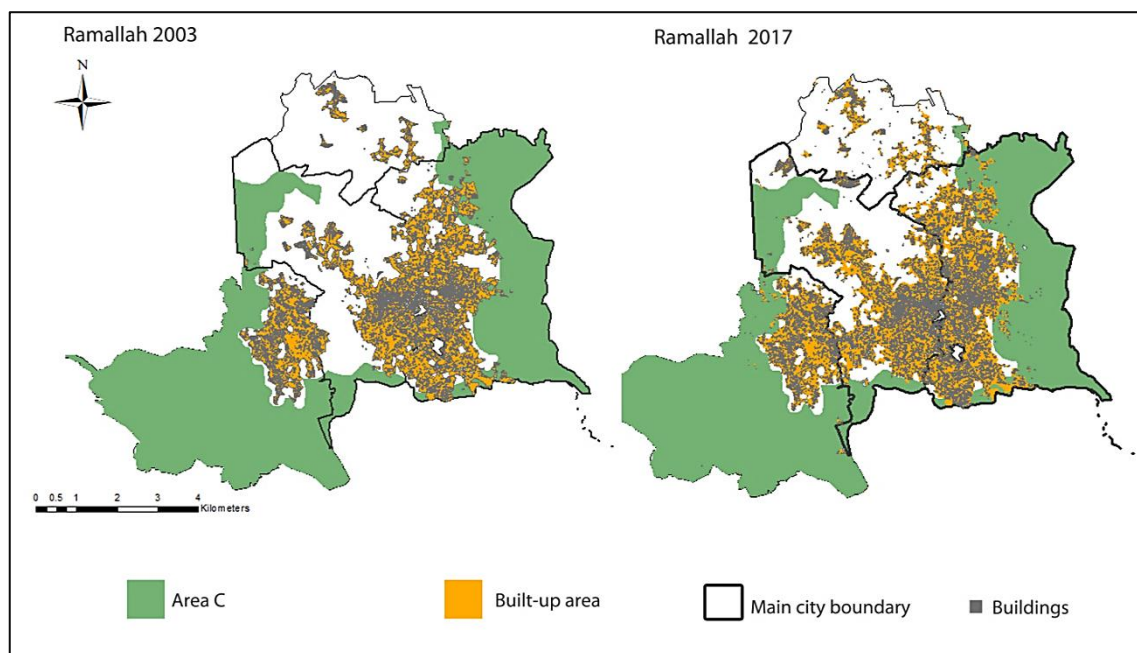


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00133	0.00123	-8.10%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
			53%	41%	6%
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		33%	37%	0.90	

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity		Fractal Dimension	1.298	1.288	-0.79%
Shape Index			2.5	2.4	-3.70%	
Compactness			0.37	0.42	14.30%	
Configuration		Contiguity Index	0.99	0.99	-0.60%	2
		Patchiness	3	8	166.6%	3
		Scatter	557	661	19%	4
		Shannon Entropy	0.843	0.846	0.4%	5

Ramallah

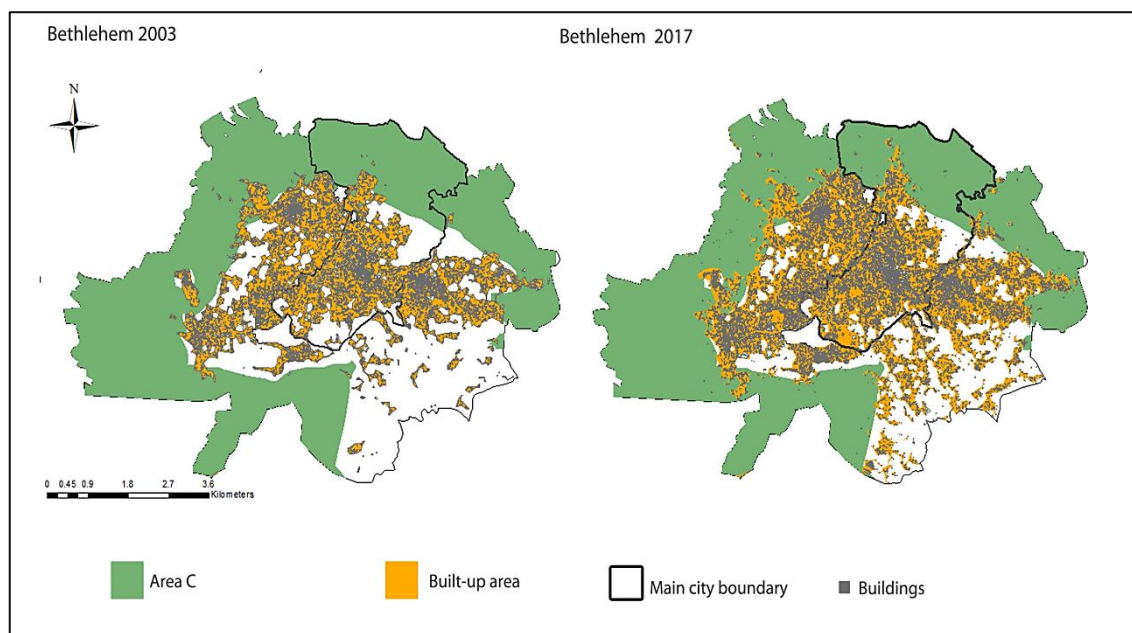


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00066	0.00061	-7.60%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		34%	47%	19%	2
	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		33%	49%	0.68	

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity	Fractal Dimension	1.331	1.333	0.14%	3
		Shape Index	3.5	4.3	23.57%	4
		Compactness	0.35	0.44	27.64%	
	Configuration	Contiguity Index	0.71	0.89	25.01%	
		Patchiness	25	48	92.00%	5
		Scatter	2089	2216	6%	6
Shannon Entropy		0.870	0.898	3.2%	7	

Bethlehem

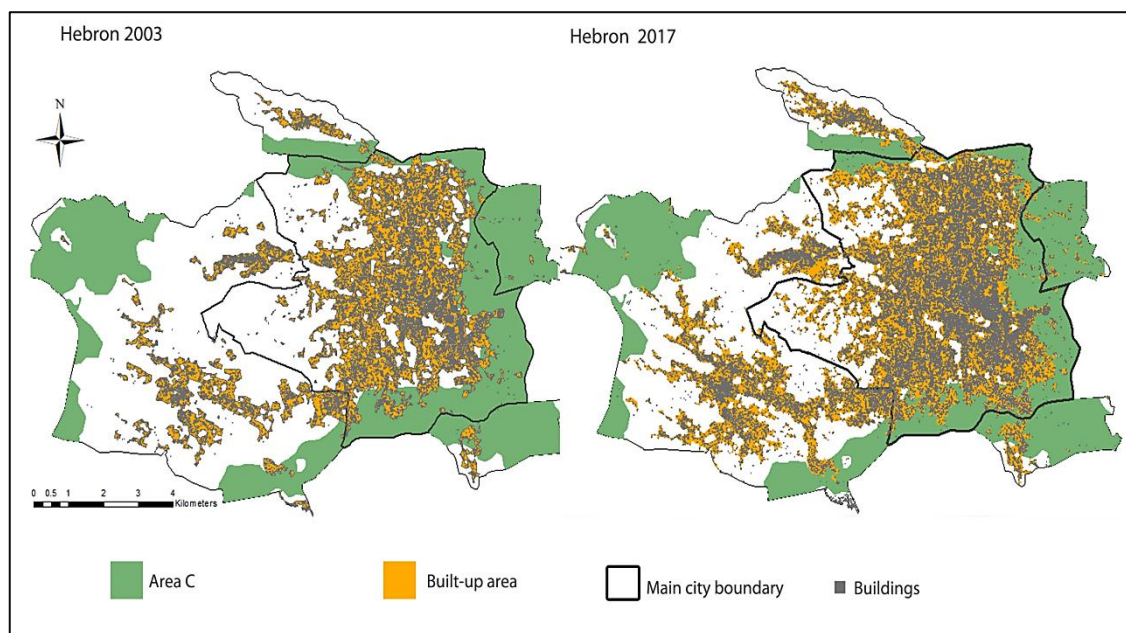


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00062	0.00053	-14.70%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		31%	47%	21%	2
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		41%	33%	1.27	3

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator
	Complexity	Fractal Dimension	1.354	1.318	-2.66%	
		Shape Index	5.0	3.9	-21.69%	
		Compactness	0.25	0.34	32.96%	
	Configuration	Contiguity Index	0.96	0.95	-0.69%	4
		Patchiness	32	37	15.63%	5
		Scatter	1877	1945	4%	6
Shannon Entropy		0.892	0.934	4.8%	7	

Hebron

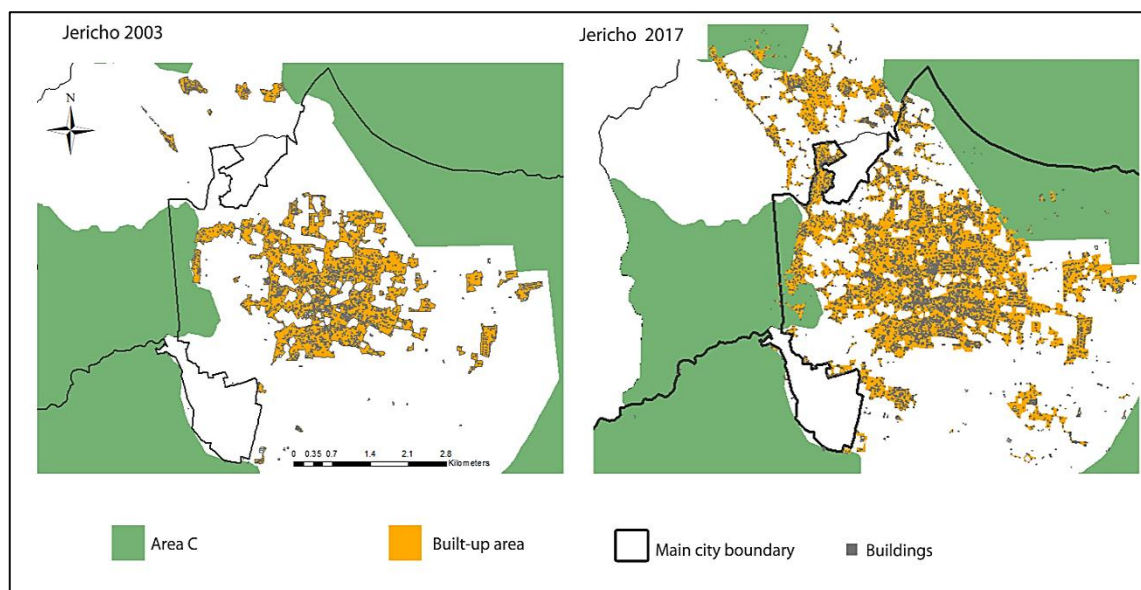


Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.00047	0.00037	-22.30%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
			51%	44%	5%
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
			57%	43%	1.33

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator	
	Complexity	Fractal Dimension		1.332	1.369	2.82%	3
		Shape Index		3.9	7.1	80.03%	4
		Compactness		0.45	0.36	-20.15%	5
	Configuration	Contiguity Index		0.72	0.95	31.77%	
		Patchiness		76	86	13.16%	6
		Scatter		3078	3236	5%	7
Shannon Entropy			0.904	0.924	2.2%	8	

Jericho



Dimension	Indicator	2003	2017	Percent change	Sprawl indicator
Density	Density Gradient	0.0011	0.00096	-13.10%	1

Growth	Growth patterns	In-fill growth percentage	Extension growth percentage	Outlying growth percentage	Sprawl indicator
		20%	60%	19%	2
Growth	Pop. Growth Vs built up area growth	Percent change in built up area	Percent change in Population	index	Sprawl indicator
		125%	22%	5.73	3

Spatial geometry	Indicator	Parameter	2003	2017	Percent change	Sprawl indicator	
	Complexity	Fractal Dimension		1.343	1.351	0.56%	4
		Shape Index		3.4	3.9	15.18%	5
		Compactness		0.29	0.32	10.66%	
	Configuration	Contiguity Index		0.78	0.72	-8.29%	6
		Patchiness		27	65	140.7%	7
		Scatter		1420	2027	43%	8
Shannon Entropy			0.741	0.813	9.7%	9	

Appendix 4

Ranking Procedure

1. Ranking the pattern of sprawl in 2017 (out of 100)

Table 1: Ranking of urban areas according to sprawl parameter values in 2017 (worst to best, left to right)

Dimension	Indicator	10	9	8	7	6	5	4	3	2	1
Density	Density Gradient	Hebron	Nablus	Bethlehem	Ramallah	Qalqilya	Jenin	Jericho	Tulkarem	Salfit	Tubas
Growth	Growth Rates of Population Versus Built-up Area	Jericho	Nablus	Tubas	Tulkarem	Jenin	Hebron	Bethlehem	Qalqilya	Salfit	Ramallah
	Growth patterns (outlying)	Bethlehem	Jericho	Ramallah	Tubas	Jenin	Tulkarem	Salfit	Hebron	Nablus	Qalqilya
Urban form	Fractal dimension	Hebron	Tubas	Jericho	Jenin	Tulkarem	Nablus	Ramallah	Bethlehem	Salfit	Qalqilya
	Shape Index	Hebron	Nablus	Jenin	Tulkarem	Ramallah	Tubas	Jericho	Bethlehem	Salfit	Qalqilya
	Compactness	Nablus	Jenin	Tubas	Jericho	Bethlehem	Hebron	Tulkarem	Salfit	Ramallah	Qalqilya
	Contiguity Index	Jericho	Ramallah	Tubas	Tulkarem	Bethlehem	Jenin	Hebron	Nablus	Salfit	Qalqilya
	Patchiness	Hebron	Jericho	Ramallah	Jenin	Bethlehem	Tubas	Nablus	Tulkarem	Salfit	Qalqilya
	Scatter	Hebron	Nablus	Ramallah	Jericho	Bethlehem	Tulkarem	Jenin	Tubas	Qalqilya	Salfit
	Shannon Entropy	Nablus	Qalqilya	Bethlehem	Hebron	Tulkarem	Ramallah	Jenin	Tubas	Salfit	Jericho

2. Ranking the process of sprawl (from the most changing to least changing towards sprawl) (out of 100)

Table 2: Ranking of urban areas from the most changing to least changing toward sprawl (left to right)

Dimension	Indicator	10	9	8	7	6	5	4	3	2	1
Density	Density Gradient	Tulkarem	Hebron	Jenin	Tubas	Nablus	Qalqilya	Bethlehe m	Jericho	Salfit	Ramallah
Growth	Growth Rates of Population Versus Built-up Area	Jericho	Nablus	Tubas	Tulkarem	Jenin	Hebron	Bethlehe m	Qalqilya	Salfit	Ramallah
	Growth patterns (outlying)	Bethlehe m	Jericho	Ramallah	Tubas	Jenin	Tulkarem	Salfit	Hebron	Nablus	Qalqilya
Urban form	Fractal dimension	Hebron	Qalqilya	Jenin	Tubas	Jericho	Ramallah	Salfit	Tulkarem	Nablus	Bethlehe m
	Shape Index	Hebron	Jenin	Tubas	Qalqilya	Tulkarem	Ramallah	Nablus	Jericho	Salfit	Bethlehe m
	Compactness	Hebron	Qalqilya	Jenin	Nablus	Tubas	Jericho	Salfit	Tukaram	Ramallah	Bethlehe m
	Contiguity Index	Jericho	Bethlehe m	Salfit	Tubas	Qalqilya	Jenin	Ramallah	Nablus	Hebron	Tulkarem
	Patchiness	Tubas	Salfit	Jericho	Jenin	Ramallah	Qalqilya	Nablus	Bethlehe m	Hebron	Tulkarem
	Scatter	Tubas	Jericho	Jenin	Salfit	Tulkarem	Qalqilya	Nablus	Ramallah	Hebron	Bethlehe m
	Shannon Entropy	Jericho	Qalqilya	Jenin	Bethlehe m	Tulkarem	Nablus	Ramallah	Tubas	Hebron	Salfit

3. Over all Ranking of Sprawl

Table 3: Ranking urban areas according to their overall value of sprawl from the highest to lowest

Urban Area	Number of sprawl indicators /10	Pattern of sprawl according to value in 2017 /100	process of sprawl (the most changing to least changing) /100	Overall sprawl value/210	sprawl percentage (293=100%)
Jericho	9	69	73	151	72%
Jenin	9	61	73	143	68%
Tubas	9	57	73	139	66%
Hebron	8	74	55	137	65%
Nablus	7	70	46	123	59%
Tulkarem	6	61	48	115	55%
Bethlehem	7	60	41	108	51%
Ramallah	7	58	39	104	50%
Qalqilya	8	26	59	93	44%
Salfit	5	22	43	70	33%

جامعة النجاح الوطنية
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إعداد

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إشراف

د. عماد دواس

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة التخطيط الحضري والاقليمي، بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس - فلسطين.

2019

ب

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الملخص

لا تزال ظاهرة الزحف العمراني في فلسطين ظاهرة غير مدروسة بعمق، والابحاث العلمية التي تتناول هذا الموضوع تفتقر الى القواعد النظرية والادلة العملية على حد سواء. يهدف هذا البحث الى معرفة ما اذا قد اظهرت المناطق الحضرية الفلسطينية في الضفة الغربية أنماطاً عشوائية في توسعها العمراني بين العامين 2003 و2017، اضافة الى ذلك، سيقوم هذا البحث بمقارنة هذه المناطق ببعضها البعض بالاستعانة بالنتائج العملية والاحصائية، ووضع تصور لتعريف هذه الظاهرة ضمن السياق الفلسطيني.

يتناول هذا البحث الزحف العمراني كظاهرة متعددة الأبعاد بدلا من اعتبارها ذات بعد واحد لتحقيق فهم اكثر شمولية، ويرتكز التحليل على عدد من المتغيرات المكانية المستتبطة من الابحاث العلمية والتي يتم فيها تحليل الزحف العمراني ببعديه المكاني والزمني، وتشمل هذه المؤشرات دراسة الكثافة الحضرية، النمو الحضري، والشكل العمراني للمنطقة المبنية، ويستخدم البحث نظم المعلومات الجغرافية بشكل اساسي لإجراء التحليل وذلك بالاستفادة من المزايا التحليلية المكانية التي يقدمها النظام.

تعتمد دراسة الزحف العمراني في هذا البحث على المقاييس النسبية، بحيث انه لم يتم تحديد قيمة فاصلة بين ما يمكن اعتباره عشوائيا ام لا، عوضا عن ذلك، سيقوم البحث بدراسة التغير في قراءة المؤشرات بين عامي 2003 و2017 لمعرفة ما اذا قد ازداد الزحف العشوائي فيها ام لا، ومن ثم مقارنة المدن الفلسطينية بناء على القيم النسبية التي اظهرتها بين بعضها البعض.

في الجانب الأول للدراسة، وهو جانب الكثافة الحضرية، تم اعتماد مقياس تدرجات الكثافة العمرانية كمؤشر على وجود الزحف العمراني العشوائي، بحيث تم من خلال دراسته تقييم العلاقة بين الكثافة العمرانية والمسافة من المركز الحضري، اضافة الى دراسة التغير في قيمة المؤشر بين عامي الدراسة ، والذي سمح لنا بمعرفة اذا ما قد اظهرت المناطق نمطاً عشوائياً في تمددها، بالإضافة الى مقارنة المدن ببعضها البعض وترتيبها من الأعلى تغيراً الى الأقل تغيراً. وقد اظهرت نتائج قياس هذا المؤشر بان جميع المدن الفلسطينية بدون استثناء قد اظهرت انحداراً في منحني تدرج الكثافة بنسب مئوية مختلفة.

اما جانب النمو الحضري فقد تمت فيه مقارنة معدلات الزيادة السكانية بمعدلات الزيادة في مساحة المنطقة المبنية، وقد اظهرت نتائج التحليل أن معدلات الزيادة في المساحة المبنية قد تجاوزت الزيادة السكانية في معظم مناطق الدراسة مما يدل على وجود الزحف العمراني العشوائي، كما قد تم في هذا الجانب دراسة انماط التمدد العمراني بمختلف انواعها والتي قد ظهرت في فترة الدراسة.

اما الجانب الأخير والذي قد تناول دراسة الشكل الهندسي للمنطقة المبنية، فقد تم من خلاله تحليل نوعين من المؤشرات: مؤشرات تختص بدراسة التعقيد في الشكل الهندسي، ومؤشرات تختص بدراسة التشتت بين المساحات المبنية والعلاقة بينها، بإجمالي سبعة مقاييس لهذا الجانب. وقد خلصت نتائجها الى ان المناطق الفلسطينية تمتلك بنية قوية وتتميز بأشكال بسيطة ذات مركزية عالية، ولكن التغير في القيم بين عامي الدراسة اظهر ان هذه البساطة والمركزية قد انحدرت خلال فترة الدراسة بنسب متفاوتة كمظهر من مظاهر التمدد العشوائي.

ويخلص البحث في النهاية الى ان جميع المناطق الفلسطينية قيد الدراسة قد اظهرت انماطاً مختلفة من مظاهر التمدد العمراني العشوائي بنسب متفاوتة، وبناء على هذه النتيجة فقد أوصى البحث بأهمية التخطيط السليم والشامل من قبل المخططين وصناع القرار في المساهمة في الحد من هذه الظاهرة التي تؤثر سلباً على جميع مظاهر التنمية المستدامة وخصوصاً في ظل الأوضاع

الجوسياسية التي يعيشها الشعب الفلسطيني والمتمثلة في محدودية المصادر والاراضي المخصصة
للتوسع المستقبلي.