

Characteristics of spatio-temporal urban growth patterns due to the driving forces of urbanization: The Coastal City of Antalya, Turkey

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Characteristics of spatio-temporal urban growth patterns due to the driving forces of urbanization: *The Coastal City of Antalya, Turkey*

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Abstract: Urban growth patterns are a reflection of how urbanization is affected by physical geography as well as by the economic, social, and natural factors of individual cities. Therefore, an analysis of any urban growth pattern triggered by these factors by using measurable variables can make a significant contribution towards the determination of future spatial growth strategies. This paper aims to characterise and evaluate the urban growth pattern of Antalya, a coastal city in Turkey, that occurred between 1987 and 2016. To achieve this, a multi-temporal analysis of satellite images was carried out to determine the city's urban growth patterns in 1987, 2000, and 2016, and spatial growth indices were then used to identify three urban growth types – sprawl, infill, and leapfrog. The results clearly show that the amount of built-up area in Antalya increased considerably after 2000, and is estimated to have grown by a factor of eight over the period covered by this study, predominantly through the processes of sprawl and leapfrog development.

1. INTRODUCTION

Demands for land use result in the conversion of natural areas and also accelerates urbanization, thereby creating pressure on the natural environment (Pickett et al., 2001; Sekovski, Newton, & Dennison, 2012). Maintaining the link between sustainability and urban form requires a balance that allows sustainable urban growth, but urbanization and the spread of built-up areas can lead to a series of unintended results. These often include an increase in impervious surfaces, changes to surface water drainage lines, disruption of the hydrology cycle, and negative microclimatic effects (Erell, Pearlmutter, & Williamson, 2011; McCarthy, Best, & Betts, 2010; Yilmaz & Terzi, 2018). Arguably, the most serious reasons for the latter are the creation of intense/high heat islands (Gartland, 2010; Jusuf et al., 2007; Li, Y. y., Zhang, & Kainz, 2012), and increased greenhouse gas emissions (McCarthy, Best, & Betts, 2010). In addition, urbanization around rivers and surface water drainage areas adversely affects the ecosystems and habitats often present at the land-water transition point. This gives rise to a requirement that in such cases the specific type of urban growth should be

identified and taken into consideration during any planning processes to reduce the pressures created by urbanization. Thus, the continuity of surface water drainage lines, local microclimate features, and the presence of impermeable surfaces have become critical issues for many involved in the promotion of sustainable growth.

The types of spatial growth that occur within built-up areas can be characterized by their geographical features and natural thresholds in addition to their pattern of spatio-temporal change ([Abrantes et al., 2017](#); [Herold, Scepan, & Clarke, 2002](#)). Naturally, these geographical features and thresholds have a considerable effect on a city's spatial growth ([Yilmaz & Terzi, 2019](#)) and there may be differences of form that arise from social and economic factors as well as from planning policies ([Wilson et al., 2003](#); [Wu, K.-y. & Zhang, 2012](#)). No matter the cause, unsustainable city growth inevitably results in the destruction of natural areas. However, spatial growth is not immune to the external limits imposed by nature, and although it can affect environmental factors such as the local micro-climate, it is also affected by its surrounding environment due to the existence of features such as slopes, natural barriers, and water aquifers ([Angel, Sheppard, & Civco, 2005](#)). Taken as a whole, these effects often result in three main types of urban growth: infill, sprawl (expansion), and leapfrog ([Wilson et al., 2003](#); [Wu, Y., Li, & Yu, 2016](#)). As they face a wider range of co-existing natural thresholds, the development patterns of coastal cities are more pronounced, and given the increasing concern for sustainable development, the urban spatial growth of these cities should be managed to allow the ecosystems within the land-water transition zone to continue to function.

Many researchers have underlined the importance of providing continuity for areas of ecologically sensitive green infrastructure without interrupting them with urban development. According to [Dramstad, Olson, and Forman \(1996\)](#), significant natural corridors such as streams and rivers, allow ecological integrity to be maintained, but the space set aside for these corridors has been steadily decreasing due to the continuous encroachment of artificial surfaces. Keeping these corridors intact is vitally important in terms of maintaining a healthy ecology, sustainable land use, and quality links between the habitats of viable wildlife populations. Built-up areas that disconnect green corridors, greenways and green networks cause fragmentation and endanger the survival of such habitats ([Forman, 2014](#)). In many cases, the vulnerable undeveloped lands and natural areas in and around cities are one of the main elements that ensure the continuity of green connections and sustain ecosystem functions such as forests and water supplies. Naturally, areas such as green belts, fringe belts ([Gu, 2010](#); [Whitehand & Morton, 2004](#)), corridor connections (the riparian region and valleys), and coastlines must be protected by extensive land-use regulations to restrict and shape built-up areas. The planning of such protection can best be done through the analysis of urban patterns according to measurable variables, as this will allow for more comprehensive urban development strategies. For example, in coastal regions where several ecosystems interconnect there should be an evaluation of which development strategies can be applied to achieve the best and most sustainable results.

There are various quantitative assessment methods for measuring urban growth. These include cellular automata-GIS ([Li, X. & Yeh, 2000](#)) and the 'What-if?' approach for scenario-based land use estimation ([Terzi, 2015](#)). These can be used to investigate the types of urban spatial growth according to their sprawl and growth characteristics ([Ewing, 1997](#); [Malpezzi & Guo, 2001](#); [Tsai, 2005](#)), and can also be used to measure their urban sprawl-related variables (densities, distances, and strength of centres) ([Terzi &](#)

[Bolen, 2009](#)) to allow their consequences to be observed. In recent years, studies carried out within the scope of this subject have investigated various aspects of urban sprawl such as changes in density from the urban centre to the urban periphery ([Guastella, Oueslati, & Pareglio, 2019](#)), the spatial orientation of coastal cities ([Man et al., 2019](#)), the forces driving urban expansion ([Terfa et al., 2019](#)), and the effects of urbanization on coastal ecosystems ([Todd et al., 2019](#)). The analytical tools in this process are broadly used to observe, map, and model urban patterns and growth to predict future possibilities through the use of both current and historical images ([Bhatta, 2010a](#)). These tools include spectral-temporal classification, image regression, artificial neural networks, change vector analysis, and post-image classification using geographic information system techniques and remote sensing data. In addition, [Galster et al. \(2001\)](#) and [Torrens and Alberti \(2000\)](#) offered characterized indicators for the analysis of various aspects within the conceptual definition of urban sprawl. These show the measurability of spatial growth patterns according to their density, continuity, clustering, centrality, and mixed-use characteristics. Therefore, the use of urban spatial metrics is considered to be a useful technique in the characterization of urban patterns as this takes physical geographical features into consideration and allows the benefits of sustainability to increase during the production of future strategies for coastal cities.

This paper aims to measure the urban spatial growth of Antalya – a coastal city in Turkey – through spatial growth indices, and to evaluate it in terms of sustainability by using data from 1987, 2000, and 2016. To accomplish this, the characteristics of three basic urban spatial growth types: sprawl, leapfrog, and infill were measured by using remote sensing, geographical information system data, and growth indices.

Antalya is an important tourism centre of Turkey, and it was selected as a case study area due to its history of continuous spatial growth and rapid urbanization. In particular, the impact of the tourism policies which came into effect after 1980 has become increasingly noticeable on the city's physical environment. As with other cities that have tourism-dominated economies, it is important for Antalya to maintain a balance between conservation and growth, especially in the use of its natural resources. In addition, Antalya has a second area of national economic and strategic importance that further complicates the issues surrounding its urban development; it is the production centre for approximately half of Turkey's entire greenhouse agriculture output (Url-1).

2. THE STUDY AREA AND ITS HISTORICAL DEVELOPMENT

Antalya is a coastal city located in southern Turkey *Figure 1*. Following the establishment of the Turkish Republic in 1923, the city experienced stable population growth and development was centred in and around the Kaleiçi district (notation 4 in *Figure 5*). To date there have been three important periods in Antalya's urbanization process – pre 1950s, the 1950s to the 1980s, and post 1980s. The stable population growth of the 1920s continued until increased industrial investment during the 1950s resulted in higher levels of urban migration. This was later joined by developments in tourism and construction to take advantage of the city's natural and cultural resources, a process which started in earnest during the 1970s. To counteract the effects of this, the 1978 Development Plan was applied to promote new growth areas to the west in order to protect the agricultural and ecological

areas in the eastern part of Antalya. However, greater numbers of vacation homes and touristic facilities led to the transformation of many agricultural areas and also put pressure on coastal areas. In 1983, the Tourism Incentive Law no. 2634 further increased tourism investment and although this brought economic and social advantages, it also resulted in environmental losses (Manavoğlu, 2012).

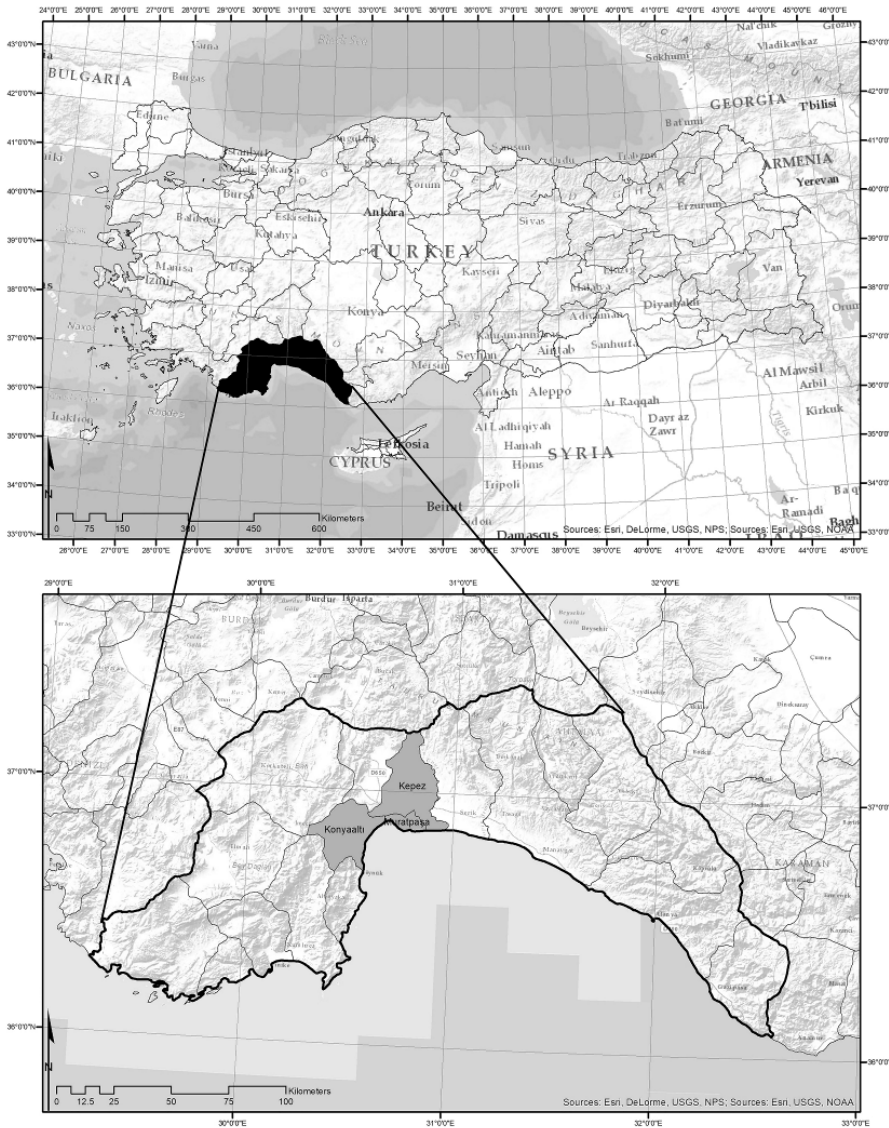


Figure 1. Location of Antalya, Turkey

While the geographical thresholds to the west and north of Antalya are its legally protected forests, the limits to the eastern region mainly consist of important agricultural areas (greenhouses). These thresholds continue to play a decisive role in shaping Antalya’s urban spatial growth (Figure 2).

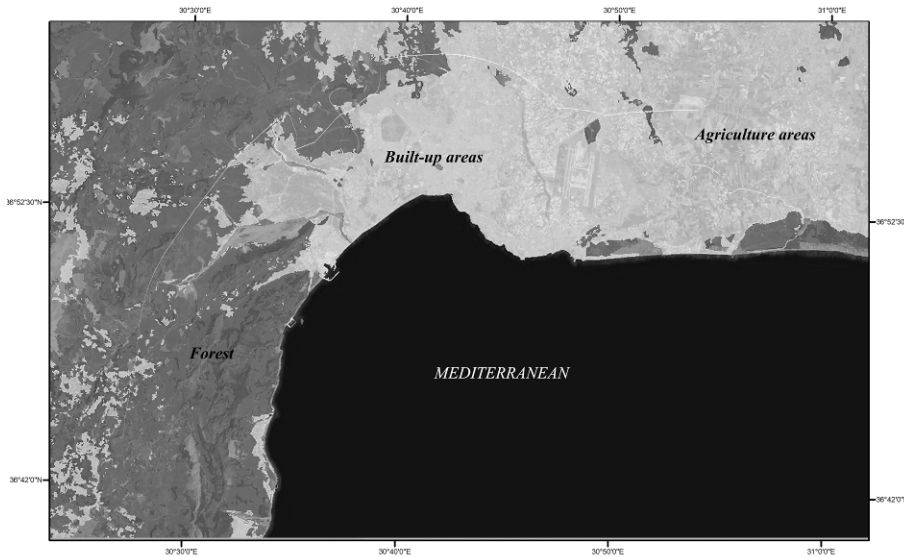


Figure 2. Dominant land cover and land use of the study area (patterns of built-up area are as shown in Figure 5)

3. METHOD

The method used in this study is comprised of the utilisation of remote sensing for multi-temporal change and the measurement of urban growth types.

3.1 Remote sensing for multi-temporal change

Table 1. Spatial information about bands used for image classification in the study (Url-3)

Bands used in the study	Landsat 8 OLI/TIRS		Landsat 7 ETM+ SCL-on (1999-2003) and Landsat 4-5 TM	
	Wavelength (μm)	Spatial Resolution (m)	Wavelength (μm)	Spatial Resolution (m)
Band 2	(Blue) 0.452 – 0.512	30	(Green) 0.52-0.60	30
Band 3	(Green) 0.533 – 0.590	30	-	30
Band 5	-	30	(SWIR1) 1.55-1.75	30
Band 6	(SWIR1) 1.566 – 1.651	30	-	* ¹ 60 / ² 120
Band 7	(SWIR2) 2.107 – 2.294	30	(SWIR2) 2.09-2.35	30

*Resolutions of Landsat 7 and Landsat 4-5, respectively.

¹Landsat 7 Band 6, spatial resolution 60 m was resized to 30 m.

²Landsat 4-5 Band 6, spatial resolution 120 m was resized to 30 m.

This study is an analysis of the urban spatial growth of Antalya using satellite images from three different dates: (1) August 10, 1987 (Landsat 5 TM), (2) August 5, 2000 (Landsat 7 ETM + SCL-on (1999-2003)), and (3) August 9, 2016 (Landsat 8 OLI/TIRS), each with a cloudiness ratio of '0' (Url-2) (Table 1). The images were processed using NNBAI (New Normalized Built-up Area Indices) and MNDWI (Modified Normalized Difference Water Index) to identify built-up areas and water surfaces using ERDAS IMAGINE software. The use of these indices has been recognised as contributing to the production of an increased accuracy ratio (Yilmaz & Terzi, 2019; Bhatti & Tripathi, 2014; Xu, 2008; Zha, Gao, & Ni, 2003) and they became a determinative factor for the classification of the images. The

index equations and bands of the satellite images used for the image classification are as follows (Yilmaz & Terzi, 2019).

The images were obtained at an 8-bit radiometric resolution (0 to 255 pixel values) and each pixel cell is equal to an area measuring 100m². However, the built-up areas and water surfaces located in different geographical positions have a range of pixel values due to the prevailing atmospheric conditions. Therefore, the pixel value range of the maps was further determined by using Google Earth open source access maps within the value ranges represented by the most likely built-up areas. The threshold values obtained from undeveloped land, built-up areas, and water surfaces were converted to values of '0' (undeveloped land), and '1' (built-up area) to create binary maps through the 'Built-up Area Indices' produced during this study. The indices are expressed as follows (1) (Yilmaz & Terzi, 2019):

$$\begin{aligned} \text{Built-up Area} &= \text{NNBAI}_v - \text{MNDWI}_v \\ \text{NNBAI}_v &: \text{Built-up area (vector data)} \\ \text{MNDWI}_v &: \text{Water surface (vector data)} \end{aligned} \quad (1)$$

(1) In the Built-up Area Indices, built-up area and water surface were assessed separately, and images were superimposed. Thus, effect of the incorrect classification on the satellite images was decreased to the extent possible.

According to Bhatta (2010b), the image processes in remote sensing offer benefits when analysing growth types, determining changes of land use/cover, and for the modelling, mapping, and monitoring of urban spatial growth. Therefore, in this study, the measuring of urban growth types was carried out using remote sensing and Geographic Information Systems (GIS) technology.

3.2 Measuring urban growth types

The development of built-up areas within and around a city causes the destruction of the natural environment. The loss of vacant land and the weakening or destruction of green corridors (e.g. hydrological areas, flora-fauna habitat corridors, and green systems) can affect the sustainability of the entire ecosystem. At the same time, the primary urban growth types – sprawl and leapfrog – lead to the ineffective use of already limited natural resources. In particular, gradual decentralization due to leapfrog growth causes an even more spread-out spatial growth pattern, again adversely affecting natural, economic, and social sustainability (Crawford, 2007).

The transformation of natural areas to built-up areas leads to various forms of urban spatial growth. However, there are three main urban growth types that form due to the effects of both natural thresholds (Forman, 1995) and urban development dynamics such as socio-economic factors (Yilmaz, 2019). These types are the sprawl of the built-up area (Wilson et al., 2003; Liu et al., 2010), leapfrog development isolated from the city centre (Harvey & Clark, 1965), and the infilling of vacant lands within the built-up area (Wu, Y., Li, & Yu, 2016; Ellman, 1997). The basic geometry of these urban growth types is given in Figure 3, and they are theoretically and hypothetically described as follows.

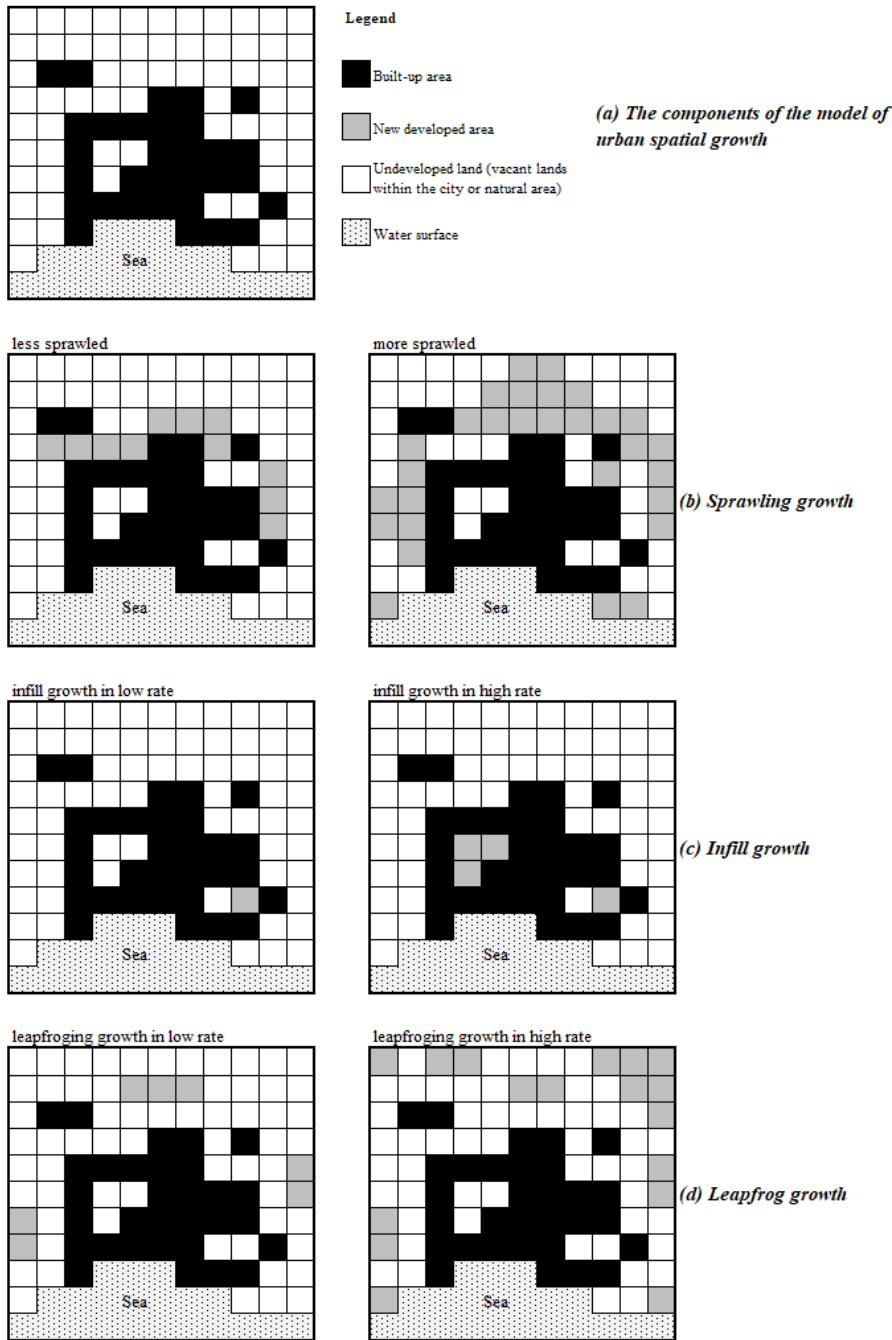


Figure 3. The geometry calculation of the characteristic of urban spatial growth (Yilmaz, 2019).

Sprawling growth

Although urban growth, expansion (sprawling growth) and sprawl are sometimes described as having the same meaning, they actually possess different forms and processes (Angel, Sheppard, & Civco, 2005; Galster et al., 2001; Ellman, 1997; Salvati, Sateriano, & Bajocco, 2013). Urban expansion is a product of continuity-based spatial growth whereas urban growth represents a spatial and demographic process. Urban sprawl is best described as a growth characteristic such as leapfrog growth, ribbon growth, and low density or uncontrolled growth (Bhatta, 2010a).

The expansion of various forms that occur within a given spatio-temporal framework (Pickett et al., 2001; Wu, Y., Li, & Yu, 2016) illustrates the process by which a natural environment is converted to accommodate ever-expanding urban facilities. Such urban expansion can be regarded as one of the most effective triggers for the negative results experienced within formerly natural areas. These results are often seen as increased energy consumption, increased air pollution, the disruption of ecosystems, discontinuous green networks, and the reduction and scattering of natural areas (Ewing, 1997; Torrens & Alberti, 2000; Burchell et al., 2005).

The index of sprawling growth used in this study was created by measuring the percentage of land consumed by spatial growth over time. The increase in spatial growth over the study period shows the trend for land consumption. The following equation (2) was used to calculate the rate of sprawling growth.

$$\text{Sprawl index} = \left(\frac{S' - S}{S} \right) \times 100 \quad (2)$$

(2) S in the sprawling index represents the total built-up area (hectares) in n years, while S' indicates the total area (hectares) built-up within the year ' $n + x$ '.

A decrease in the sprawl value shows spatial growth trending towards a less sprawling pattern; an increase designates spatial growth trending towards a more sprawling pattern (Figure 3).

Infill growth

The conversion of undeveloped land (vacant land) within the urban environment into built-up areas is classified as infill growth. In many cases, undeveloped land within cities is under constant development pressure due to the availability of infrastructure and cheaper land costs (Wilson et al., 2003; Schneider & Woodcock, 2008). However, the protection and preservation of such areas ensures the maintenance of ecological corridors and green networks, especially within and around a city. This becomes an important issue as their loss causes a discontinuous green network and decreases the amount of pervious surfaces (Forman, 1995). The removal of surface water drainage lines or valleys and the associated alteration of the microclimate becomes a critical issue as it can lead to the formation of heat islands and increase the likelihood of natural disasters such as floods and severe storms.

In this study, the type index of infill growth is measured by the conversion ratio of undeveloped land (vacant land) into built-up areas. Comparative evaluations of vacant land were made between two different periods, and the results contribute to the overall assessment regarding the conservation of vacant land. The following equation (3) was used to calculate the infill index (Figure 3).

$$\text{Infill index} = \frac{S_{bos}}{S_{yapt}} \times 100 \quad (3)$$

(3) In the infill index, S_{bos} indicates the transformation of the vacant lands in n year into the built-up area (hectare) in $n+x$ year – between the $n+x$ years - while S_{yapt} designates the total built-up area (hectare) in n year.

A decrease in the infill index value shows a decreasing loss of vacant land while an increased value indicates an increasing loss.

Leapfrog growth

Leapfrog growth refers to those built-up areas which occur separately from the main urban area ([Wilson et al., 2003](#); [Harvey & Clark, 1965](#); [Hasse & Lathrop, 2003](#)). This growth type may also occur as part of a deliberate planning policy for new sub-settlements to produce a multi-centre development pattern and random urban spatial growth ([McKee & Smith, 1972](#); [Weitz & Moore, 1998](#)). This type of growth results in increased demand for urban services ([Archer, 1973](#)), and although land speculation is a popular means to lower construction expenses, a successful development will require the extension of infrastructure and increase costs ([Bahl, 1968](#); [Fulton, 1995](#)). As a result, this type of growth often occurs on undeveloped land without the planning requirements imposed within existing urban areas ([Bahl, 1968](#)). According to [Forman \(1995\)](#), leapfrog growth results in perforation caused by disrupted green networks and degraded natural area integrity. It is also a prime example of the ineffective use of natural resources ([Crawford, 2007](#)).

In this study, the index of leapfrog growth indicates the growth of the settlement form and the value level of its fragmentation. An increase in the index value (4) defines the intensity of the leapfrog spatial growth form. Both sprawling and leapfrog growth lead to the inefficient use of resources, but as leapfrog growth spreads away from the centre, it also negatively affects urban spatial growth in terms of natural, economic and social sustainability ([Crawford, 2007](#); [Schetke & Haase, 2008](#)) (*Figure 3*).

$$\text{Leapfrog index} = \frac{A_{i_{dis}}}{A_{i_s}} \quad (4)$$

(4) In the leapfrog index, $A_{i_{dis}}$ indicates the areas (hectare) developed with the leapfrogging pattern as disconnected (isolated) from the built-up area (the city), while A_{i_s} designates the total built-up area (hectare) except for the leapfrogging growth areas.

A decrease in the leapfrog index value means a low ratio of leapfrogging growth, while an increase implies a high ratio of leapfrogging growth.

4. RESULTS

4.1 Extracting built-up areas from multi-temporal satellite images

An urban area which has been changed and transformed over time due to the growth of its built-up environment can be analysed in various ways using quantitative methods ([Wu, Y., Li, & Yu, 2016](#); [Frankhauser, 1998](#); [Herold, Goldstein, & Clarke, 2003](#)). First, it is important to note that these transformations can occur due to a number of factors, including the extension of transportation networks or increased urban functions that result in the conversion of land cover. However, if planning decisions take land use into account and more conservation-centred approaches are adopted, ecological integrity and minimal land degradation can be achieved ([Dramstad, Olson, & Forman, 1996](#)). A key component in this process is the identification of those factors which have the greatest effect on urban spatial growth. In many cases, the main transport network, in terms of both its orientation and its hierarchy, is a primary candidate for consideration ([Zhu, M. et al., 2006](#)). As quantitative measurement units, which constitute a basis for the analysis of spatial growth, are closely associated with the locations of built-up areas, their distance from each other and the connections between them, as well as their land usage, land size, and land geometry. Remote sensing data can provide a reliable and spatial dataset for these features that

include both existing and historical land coverage patterns ([Herold, Goldstein, & Clarke, 2003](#)).

This study examines a set of built-up areas, and reveals changes in their sizes and the distances between them over time. The indices used are based on the extent of the built-up area, the extent of their sub-regions and their distance from the central business district, and the size of any undeveloped land within the settlement area. Antalya's spatial growth types were then evaluated according to the index measurements (the classifications of the satellite images), and the results are given in terms of trends in sprawling growth, infill growth, and leapfrog growth.

The accuracy rate of the maps generated for the three urban growth types should be within both a substantially acceptable value range and within the scope of remote sensing. Therefore, the BAEM index process, which has an accuracy rate of 80.50% was used instead of the NDBI (Normalized Difference Built-up Index) classification ([Bhatti & Tripathi, 2014](#); [He et al., 2010](#)). Approximately 100 sample points were randomly selected to determine the accuracy of the maps obtained for the study and to classify the built-up and water surface areas. The overall accuracy of the three maps was determined to range from 91% to 94% and the Kappa statistics ranged from 0.84 to 0.90. These meet the values recommended by [Congalton and Green \(2009\)](#) and ([Zhu, Z. & Woodcock, 2014](#)). A grid of cells each representing a 1-hectare area (100m²) was then applied. The performance of the models is dependent on the accuracy and resolution of the satellite images of the study area, and these have threshold values from 0 to 255 at 8-bit resolution as given by the 'Built-up Area Indices' arranged in the context of this analysis (*Table 2, Figure 4*).

Table 2. Threshold values of satellite images

Threshold values (0 to 255)	August 10, 1987	August 5, 2000	August 9, 2016
The built-up area	$78 \leq n \leq 155$	$87 \leq n \leq 156$	$70 \leq n \leq 145$
The water surface	$194 \leq m \leq 255$	$155 \leq m \leq 255$	$182 \leq m \leq 255$

n: NNBAI

m: MNDWI

4.2 Changing urban growth pattern

The results of the indices revealed that urban spatial growth started in Antalya in the 1950s and has increased since then in several expansion phases. According to the three binary images in *Figure 6*, and as a result of the indices taken from *Figure 5* and *Figure 6*, the built-up area of Antalya developed by a factor of 2.5 between 1987 and 2000, and by a factor of 1.5 between 2000 and 2016. In addition, there has been an estimated eightfold increase in total built-up area over the last 30 years, mostly due to leapfrogging growth with partial infilling (*Table 3*). Between 1987 and 2000, around 60% of the built-up areas resulted from leapfrogging growth (*Table 3*), and a key finding was that there was a reduction in the trend towards greater urban land use over the same period. This suggests that the urban spatial growth of Antalya may be trending towards a pattern of greater density rather than continued sprawl over undeveloped land.

Table 3. Urban land conversion rate by the periods

Land use \ Years	1987		2000		2016	
	hectare	%	hectare	%	hectare	%
Built-up area	781	100	2764	100	6767	100
Built-up areas through leapfrogging	218	28	1567	57	2514	37
Vacant lands inside the city	88	-	274	-	2321	-

Satellite imagery was used to provide a means of interpretation for Antalya's built-up area growth trends, specifically the sprawling, infilling, and leapfrogging types associated with urban spatial growth. To better explain and understand the type and developmental trends of the study area, a sprawling growth index, infilling growth index, and leapfrogging growth index were calculated for 1987-2000 and 2000-2016. As shown in *Figure 4*, the growth trends for these two periods reveal a gradual decrease across all three-index values.

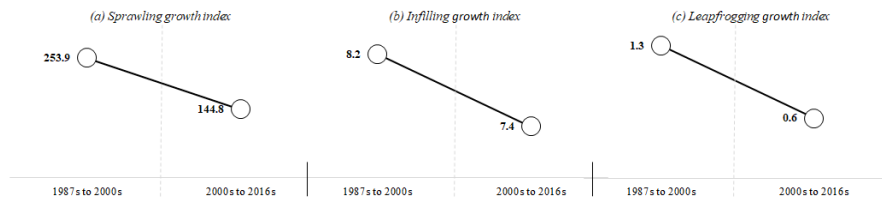


Figure 4. Changes of urban spatial growth indices by periods, 1987 to 2000, and 2000 to 2016.

In 1987, the urban spatial pattern of Antalya was mainly centred around the Kaleiçi Historical Core and was also affected by important urban facilities including the airport and seaport. As Antalya's spatial growth has continued to grow during the last 30 years, the previous leapfrog patches have gradually become connected and more dominant. As Antalya is a coastal city, the natural thresholds such as the area's topography (notation 1 in *Figure 6*) and coastline are two of the most influential elements that control its options for spatial growth (*Figure 6*). In addition, planning decisions such as the establishment of a new seaport (notation 2 in *Figure 6*), the expansion of the existing airport (notation 6 in *Figure 6*), the increased number of vacation homes, and the declaration of a tourism area to the south after 1974 have also had major effects ([Manavoğlu, 2012](#)).

As shown in *Figure 6*, Antalya has also expanded towards its key agricultural areas (notation 3 in *Figure 6*), and the previously mentioned new seaport in the south-west of the city triggered another leapfrog growth by creating an attraction point. Other important factors, such as land speculation along the coast have caused a further increase of vacation homes and tourism sites. In addition, the conversion of existing tourist facilities into residential areas along the coastal cliffs (notation 5) and their associated inland regions (*Figure 6*) has resulted in a linear spatial growth pattern to the east of the city ([Manavoğlu, 2012](#); [Utta, 1995](#)) (*Figure 6*).

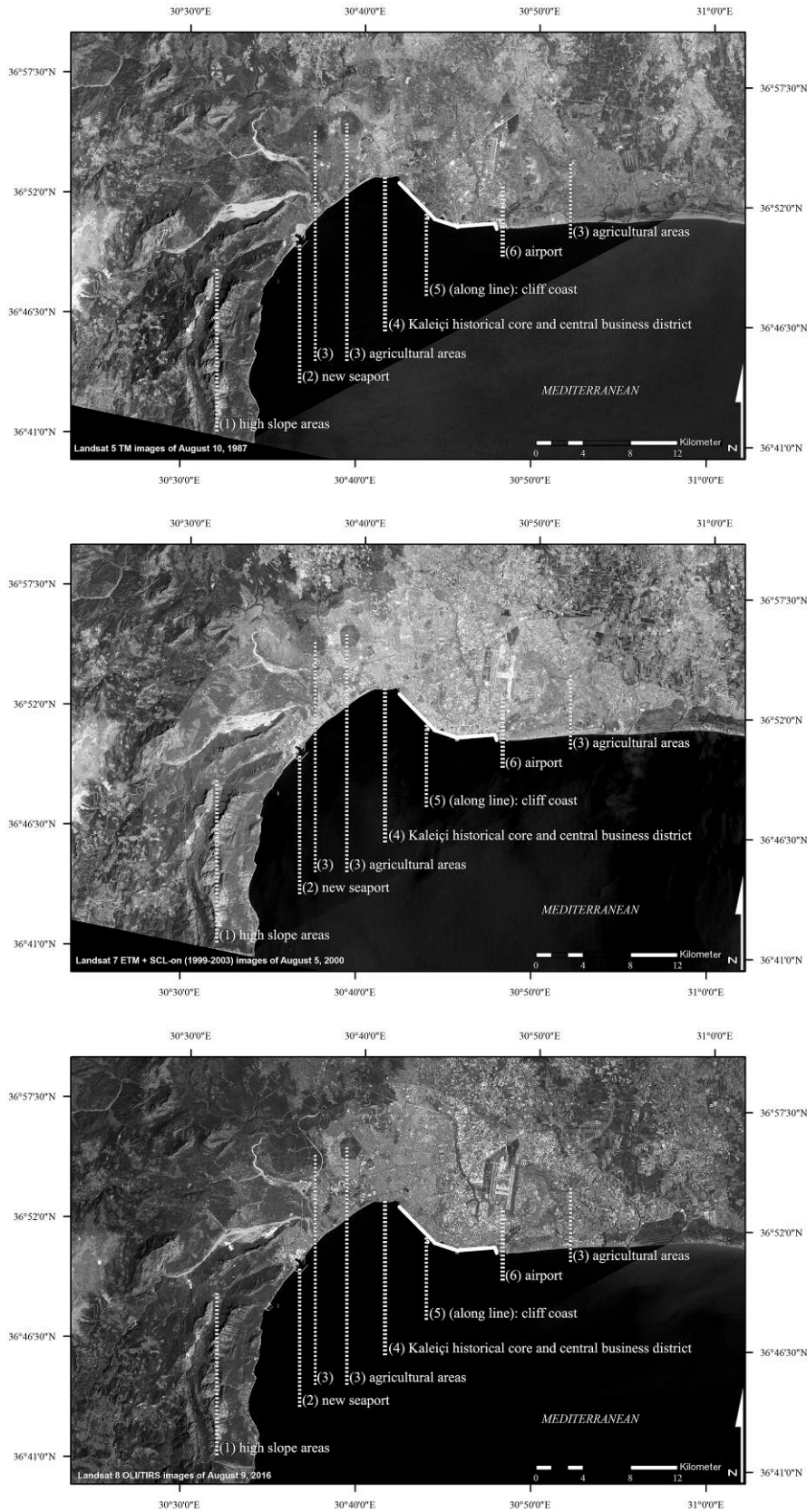


Figure 5. Satellite images of Antalya (adapted from earthexplorer.usgs.gov). Notations are representative schematic locations: 1-high slope areas, 2-new seaport, 3-agriculture areas, 4-Kaleiçi historical core and central business district, 5-cliff coast, 6-airport.

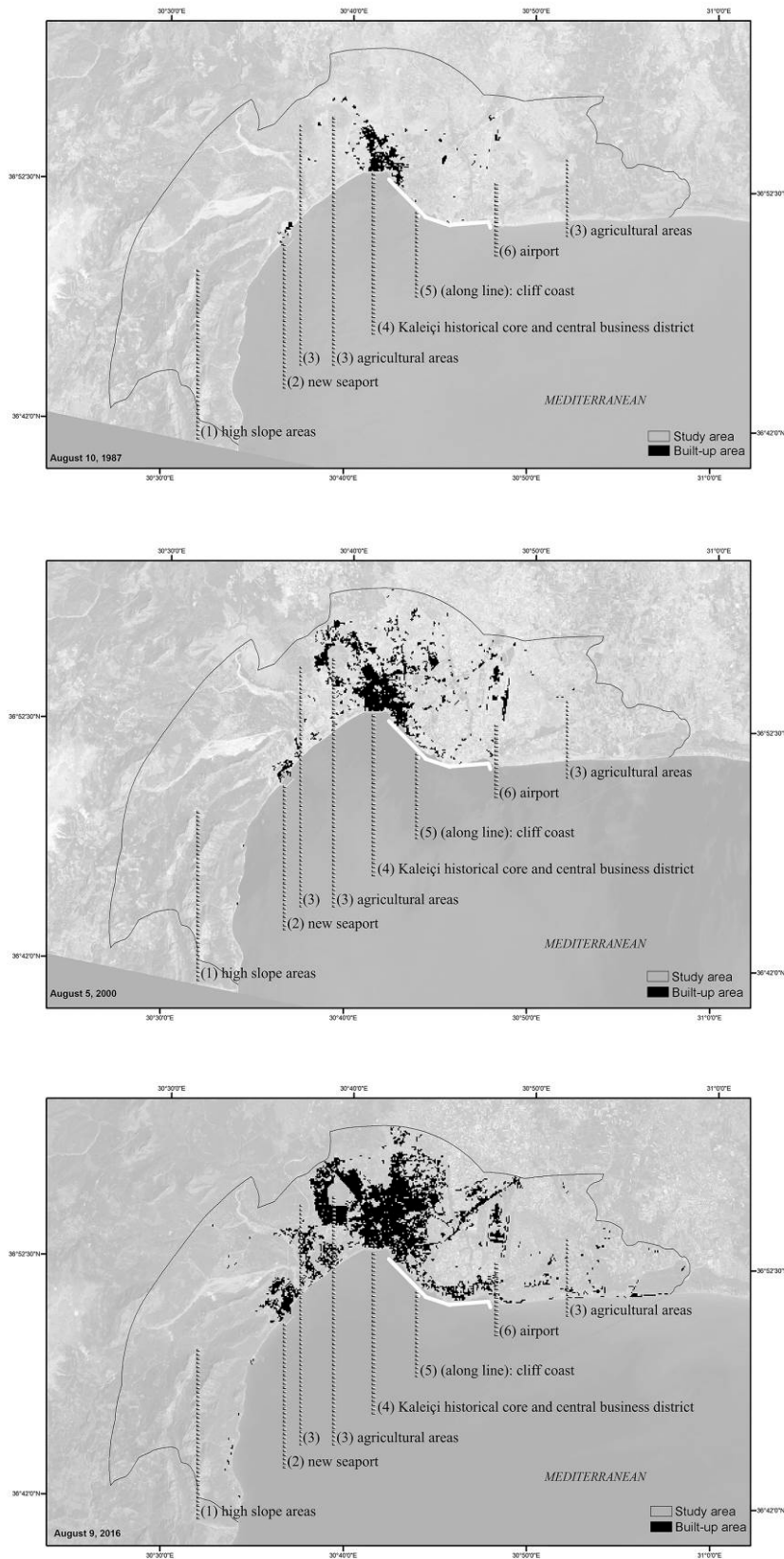


Figure 6. Urban spatial growth patterns of Antalya by year. Notations are representative schematic locations: 1-high slope areas, 2-new seaport, 3-agriculture areas, 4-Kaleiçi historical core and central business district, 5-cliff coast, 6-airport.

With regard to the type of urban spatial growth experienced by Antalya, the results of this study indicate a radial growth that starts around the central business district and spreads along the coastline. This has mostly occurred as sprawling growth due to the combining of leapfrog patches that emerged along the major roads extending north-west, north-east and north of the central business district. Additionally, new areas of urban growth have arisen around the new seaport and along the coastal cliffs (notation 5 in *Figure 6*). As a result, it is possible to state that the urban spatial growth of Antalya over the last 30 years has been predominantly leapfrog, and this unsustainable form has resulted in inefficient land use and caused the loss of natural areas. At the same time, more sprawl has occurred due to developments between the leapfrogging areas and the urban core.

In general, coasts have attractive features, and it is important to ensure their better utilization. When urban growth patterns are evaluated together with geographical thresholds, coastal cities are expected to develop along their coast. In the case of Antalya, the west and north of the city are covered with forest and high slope areas that constitute a topographic threshold. For this reason, the growth of the built-up areas is now approaching key agricultural areas (greenhouses), putting them under increased pressure. At the same time, its status as a major tourism centre means that Antalya is under pressure from the limits imposed by the coast, and from the triggers for urban growth to proceed along the coast where there are already extensive tourist facilities. These pressures have meant that other urban developments have been directed to the north-east and north-west of the city.

The predominant economic activity characteristics of coastal cities, such as tourism and agriculture, are determinative with regard to the type of urban growth a given city will experience. Urban spatial growth, especially when linked with coastal tourism, triggers an increase in the construction of vacation homes. These factors may be indicators of the need for various perspectives when attempting to define the urban patterns of coastal cities. The examination of the urban spatial growth types in this study supports the interpretation of the spatial growth tendency of coastal cities through the use of basic geometries. This evidence shows that future planning decisions and conservation approaches can be achieved when the quantitative methods proposed in this study and land-use decisions are evaluated together.

5. CONCLUSIONS

Antalya is one of Turkey's major cities, and as such it has experienced phases of mass migration and substantial urban growth that have resulted in significant changes to its urban structure. The rapid development of Antalya's economy after the 1980s, particularly in its tourism and service sectors, led to a rapid increase of its urban spatial growth. In particular, the decision to prioritise tourism, and the investments that resulted from this, have been very effective in determining the changes made to the city's urban spatial pattern. According to the index results of this study, Antalya's spatial growth has occurred predominantly towards its agricultural areas and its northern regions rather than along the coast. When the urban spatial growth types that developed between 1987 and 2000 and between 2000 and 2016 are compared, the trend towards leapfrog growth and the decrease of all other types is clearly evident.

Antalya is a coastal city which grew from the Kaleiçi Historical Core and which has experienced various urban growth trends. However, cities should not be considered only in terms of their urban development; it is also

important to preserve their pervious surfaces. For example, there is a protected natural olive grove within Antalya's urban structure. The legal protection of this area is part of a conservative policy framework, the effectiveness of which can be proved by the fact that it did not suffer any encroachment during the period covered by this study. This shows that such legal measures are worth considering to ensure that permeable surfaces within cities are not covered by infill growth. The spatial reflections of the political preferences between conservation and growth can be read through the resulting urban form. In the Antalya case, on the one hand there are agricultural areas that need to be protected against urbanization, and on the other these same areas have strong tourism potential.

This study has shown how land use policies are largely reflected in urban space and it is hoped that it will provide a means to produce better urban land use policies. The evaluation of coastal cities, with their natural thresholds, and their provision of a holistic viewpoint when compared with other cities, can also be considered to be a key area of future research.

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