



# Urban Built-Up Area Estimation and Change Detection of the Occupied West Bank, Palestine, Using Multi-temporal Aerial Photographs and Satellite Images

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## Abstract

The study aims to investigate the urban change in the West Bank between the years 1997 to 2016, under complicated geopolitical conditions. High-resolution aerial photographs (1.25 m and 0.1 m) and moderate-resolution satellite imagery (30 m resolution Landsat data) were used in this study. The results of the study showed that the Palestinians suffer from serious limitations imposed by the Israeli occupation due to the urban expansion, especially in the so-called area C, which represents 61% of the West Bank. The Israeli occupation controls this area. On the other hand, the Israeli occupation provides an opportunity to the Israeli settlers to build more houses and buildings for various purposes. The study also shows that most of the Palestinian urban expansion comes at the expense of agricultural lands. The study recommends that the international community has to place more pressure on Israel to give the Palestinians their freedom to plan for their future, and use their lands freely.

**Keywords** West Bank · Palestine · Built-up areas · Israeli occupation · Aerial photographs · Satellite images

## Introduction

This study aims to investigate the urban growth in the occupied West Bank, Palestine, between 1997 and 2016, under extraordinary circumstances and instable political conditions.

This study tries to analyze the urban expansion trends and opportunities in the West Bank over the last 20 years, in order to help decision makers to plan for the urban sector under a complex geopolitical circumstance. This also requires an analysis of other land-use types, mainly agricultural and non-agricultural lands.

Many authors have used multiple remote sensing imagery and geographic information systems (GIS) to detect urban expansion and land-use/land-cover changes. Shoukry

(2004) tried to use satellite data and GIS for the urban expansion development in the eastern part of the Nile Delta Governorates in the period 1975–1998, but the spatial resolution images were not good enough to get good accuracy for the urban area estimation. Abdelhamid (2005) used the supervised classification technique for two image periods (1984 and 2004), as well as the constructional density equation in order to detect the average change in the density of constructions in the western parts of the study area. Kittaneh (2009) studied the urban encroachment impact on the environment and agricultural lands in Ramallah and Al-Bireh in the Palestine using multi-temporal GIS and remote sensing technologies. Aerial photographs, GIS data, and satellite images were used in the study to explore the spatial and temporal advancement of urbanization in the two cities, as well as the effects of Israeli occupation on the direction of urban expansion. Lakshmi et al. (2011) used Landsat data between 1973 and 2011 to predict the urban growth of Pune by 2030, and its impact on the surrounding rural areas. Kamel (2013) studied the urban growth in the cities of Al-Fayyoun Governorate. The focus was on the factors which affected the urban growth rates at the expense of agricultural lands.

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Ta'ani (2014) investigated and evaluated the urban growth in the city of Al-Hufuf in Saudi Arabia between the years 1984 and 2010. The study used remote sensing data and GIS techniques. Mohammad (2014) used remote sensing data and GIS for creating a geodatabase for the flood plain of Qina Centre in Egypt. Mohapatra et al. (2014) focused their studies on the implications of urban expansion across geomorphology in the historical city of Gwalior, in Central India. Landsat images were used to detect the urban expansion. Abu Bakr et al. (2015) used four satellite images from 1984, 1996, 2002, and 2010, as well as GIS, to determine the extent of the urban area growth in Tripoli, Libya, in five different directions. They made an assessment of the urban expansion trends in the study area. Fadda et al. (2016) analyzed the population growth and urbanization trends in the Muscat Governorate in Oman. The authors used remote sensing data and GIS to conduct the analysis. Al-Mazroui et al. (2017) used eight images of Jeddah, Saudi Arabia, between 1973 and 2014. The study used MSS, TM, and ETM Landsat data to generate changes in the urban area in the city of Jeddah. Al-Tuwaijri et al. (2018) used multi-temporal remote sensing data and GIS (1987–2017) to estimate the urban expansion of the city of Riyadh.

## The Study Area

### Geopolitical History

The study area represents the West Bank of the River Jordan. It lies between the latitudes 31°20' and 32°38' N and between the longitudes 34°53' and 35°31' E. The surface area of the West Bank including the north-western part of the Dead Sea and East Jerusalem is 5860 km<sup>2</sup>. Its length from north to south is around 130 km, and its average width from west to east is 40 km.

In 1967, Israel occupied the Palestinian West Bank and Gaza Strip, The Egyptian Sinai Peninsula, and the Syrian Golan Heights. The Palestinians began life under the full control of Israeli forces, and all aspects of Palestinian life in the West Bank and Gaza Strip were controlled by Israeli authorities, including the housing and urban sector. In September 1993, Israel and the Palestinian Liberation Organization (PLO) signed an interim agreement called the Oslo Accord (Fig. 1c). This Accord was agreed to last only 5 years, and ended with the establishment of an independent Palestinian State in the West Bank and Gaza Strip. According to this Accord, the Palestinian Authority is to be established in the West Bank and Gaza Strip, and the West Bank would be divided into three geopolitical areas: area A, area B, and area C. Area A is to be put under the full control of the Palestinian Authority, as it represents

approximately 18% of the surface area of the West Bank, while area B which represents about 22% is to be put administratively under the Palestinian control while maintaining security issues in the hands of the Israeli occupation authorities. Area C, which represents about 60% of the total area of the West Bank, is to remain under the full control of the Israeli occupation authorities. As of 2015, area C is home to 300,000 Palestinians across 532 residential areas (Ocha 2015). It is also occupied by 389,250 Israeli settlers across 135 settlements, as well as 100 outposts which are unrecognized by the Israeli government. According to international law, the transfer of the population of the occupied state to the occupied lands is prohibited. Therefore, all Israeli settlements in the occupied West Bank are illegal. The expansion area given to the Israeli settlements is nine times their present area (Btselem 2014).

Area C forms a contiguous territory, while Areas A and B were subdivided into 165 separate units of land that have no territorial contiguity. Most of the area C has been of benefit to the Israeli settlers at the expense of the Palestinian communities. Palestinians do not have the rights to use their land resources, plan, and construct the infrastructure. Also, the Palestinians do not have means to apply the Palestinian laws.

The Palestinians in area C live in a complex situation, where road blocks, segregation walls, checkpoints, settlements, and military camps spoil their daily life. Area C hampers access by humanitarian organizations to the Palestinian communities. The lack of Palestinian planning and zoning in area C means that most Palestinians cannot obtain permits to build or renovate their homes, or build livestock sheds, or set up vital infrastructure. Israeli occupation authorities routinely demolish Palestinian buildings, including houses built without their permission, and displace the population by force.

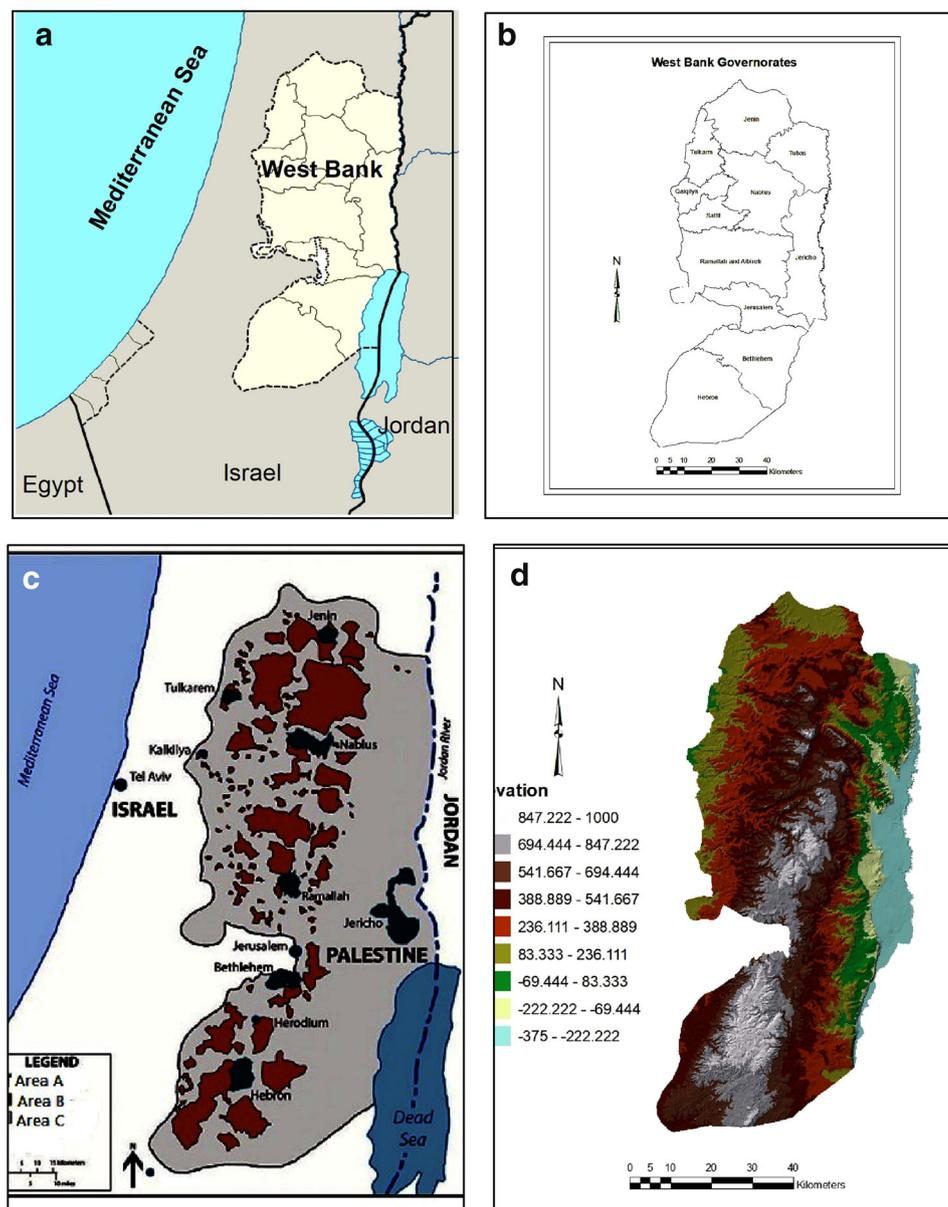
In 2013, Israeli forces demolished 565 Palestinian buildings in area C; 208 of them were houses, and this resulted in the displacement of 805 Palestinians, half of them were children (Ocha 2015).

About 70% of the Palestinian lands in area C lies within the settlement's regional councils. The Palestinians are not allowed to use these lands or develop them (Miftah 2018).

### Administrative Setup

The West Bank is a modern term given to the Palestinian territories that remained unoccupied by Israel after the 1948 war. It was annexed to Jordan after the Jericho conference held in 1950 between Palestinian and Jordanian leaders (Ennab 1979). According to this conference, the people of the West Bank became Jordanian citizens, but in

**Fig. 1** **a** The study area, **b** West Bank Governorates, **c** Oslo II outlining A, B, and C, and **d** topography of the study area



1988 Jordan decided to disengage the legislative, administrative, and financial ties with the West Bank.

The West Bank is bordered to the east by the Jordan River and the north-western shores of the Dead Sea, and to the north, west, and south by the Jordanian–Israeli ceasefire line signed in 1949.

In 1957, the Jordanian government divided the West Bank into three districts: Nablus district, Jerusalem district, and Hebron district. Nablus district included the sub-district of Nablus, Jenin, and Tulkarem.

In 1966, the Jordanian government divided the West Bank again into 11 governorates: Jenin, Tubas, Tulkarem, Qalqilia, Salfit, Nablus, Ramallah, Jerusalem, Jericho, Bethlehem, and Hebron.

In 1967, Israel authorities occupied the West Bank, Gaza Strip, the Syrian Golan heights, and the Egyptian Sinai Peninsula. Israeli occupation divided these occupied areas into four military areas: (a) the Syrian Golan heights; they called it ‘Golan heights,’ (b) the West Bank excluding East Jerusalem; they called it ‘Yahuda & Samaria,’ (c) Gaza Strip and northern Sinai; they called it ‘Shlomo,’ and (d) Southern Sinai; they called it ‘Shlemar’ (Bushnaq 2013).

In 1981, the Israeli occupation created the so-called Civil Administration in the West Bank and divided it into seven administrative and military areas: Jenin, Tulkarem, Ramallah, Jericho, Nablus, Bethlehem, and Hebron (East Jerusalem was excluded).

Between 1994 and 1995, Israel withdrew its forces from the Palestinian cities and handed them to the Palestinian Authority according to Oslo II interim agreement signed between the PLO and Israel in 1993. The Palestinian Authority has adopted the Jordanian administrative division of the West Bank with minor amendments to the borders of the governorates.

### Topographic Characteristics

The West Bank can be divided into four topographical regions:

- (a) **The Semi-Coastal region:** It lies in the western part of the West Bank. Its elevation is between 40 and 500 m above the mean sea level. It is characterized by gentle slopes, fertile soil, moderate climate, high population density, and dense vegetation cover. This region belongs to the Mediterranean Sea Climate.
- (b) **The Mountainous region:** It represents the backbone of the West Bank. Its elevation is between 500 and 1020 m above the mean sea level. Major cities lie in this region (Nablus, Ramallah, Jerusalem, Bethlehem, and Hebron). It belongs to the Moderate Mediterranean Sea Climate. It is characterized by moderate-to-steep slopes and moderate vegetation cover.
- (c) **The Eastern Slopes region:** It lies in the eastern part of the West Bank. Its elevation is between 500 m above the mean sea level to zero m at the mean sea level. It is characterized by steep slopes, poor soil, sparse vegetation cover, and very low population density. It belongs to the Semiarid Climate.
- (d) **The Jordan Valley:** It lies in the eastern part of the West Bank. Its elevation is between zero m at the mean sea level to 400 m below the mean sea level near the Dead Sea. It is characterized by gentle slopes, low population density, hot and dry weather. Agricultural lands are limited and exist on the alluvial fans near the outlets of seasonal wadis.

More than 95% of the total population of the West Bank live in the Semi-coastal and the Mountainous regions.

### Population Distribution

The Palestinian population of the West Bank for the year 1997 was 1,810,309, and became 2,972,060 in 2016 (PCBS 1997). The number of Israeli settlers in the West Bank including East Jerusalem for the year 2016 was 592,200 (Central Intelligence Agency 2018). The international community considers Israeli settlements in the West Bank including East Jerusalem illegal under international law, though Israel disputes this (Roberts 1990). Growth rate per

annum for the year 1997 was 3.2%, while for the year 2016 it was 2.55%.

Table 1 shows that the lowest population increase percentage was for the East Jerusalem governorate, and this was due to the obstacles mentioned earlier, i.e., the Israeli occupation imposed on the Palestinians in the governorate. On the other hand, the highest population increase was for the governorates of Tubas, Bethlehem, and Hebron; and this was mainly due to the Bedouin style of life in many localities in these governorates.

Figure 1c shows the Oslo II geopolitical areas A, B, and C. Areas A and B which were given to the Palestinians are fragmented by area C, which enables the Israeli Occupation Authorities to prevent the Palestinians from moving freely from one place to another in the West Bank. Therefore, Israeli occupation authorities have put road blocks and check points on most of the main roads separating main cities from each other, and from rural communities.

The West Bank has become increasingly economically active, and the housing sector remarkably improved, particularly after 1994, when the Palestinian Authority administration controlled around 40% of the land (areas A and B). But, after 24 years of signing the Oslo Accords, without seeing an independent Palestinian State, the Palestinians have begun to suffer a serious lack of land possession for building new houses and roads to meet the natural population growth and their needs. For example, the city of Qlqilia has been besieged by the segregation wall, and the people there have no space to build new houses. The people have started to leave their own city. The Palestinian Authority requested a conversion of more C areas into A and B areas in order to let people build new houses for new families, but the Israeli occupation authorities refused this request under the pressure of the Israeli settlers (timesofisrael.com 2017).

### Data and Methodology

Two satellite images and two mosaics of the aerial photographs for the West Bank were used to accomplish this study (Table 1). Free Landsat images were acquired from the NASA website between the years 1997 and 2016. The mosaics of these aerial photographs were for the same dates and areas and were obtained from the Palestinian Ministry of Local Government (MoLG). It was purchased from Israeli companies, because Israel does not allow the Palestinian Authorities to use, or hire planes to acquire aerial photographs. All data sets were cloud free, and land cover appears clearly on both satellite images and aerial photographs. Satellite images and aerial photographs were geo-referenced to the same projected coordinate system (Palestine Grid 1923).

**Table 1** Areal extent and population of West Bank Governorates, 1997–2016. *Source:* Palestinian Central Bureau of Statistics (PCBS), 1997

	Governorate	Area (km <sup>2</sup> )	1997	2016	Population change	Change %
1	Jenin	583	195,299	322,946	127,647	65
2	Tulkarem	246	129,030	187,631	58,601	45
3	Tubas	401	35,216	67,690	32,474	92
4	Qalqilia	171	69,268	114,994	45,726	66
5	Salfit	203	46,688	73,183	26,495	57
6	Nablus	601	251,392	394,197	142,805	57
7	Jericho	592	31,501	54,232	22,731	72
8	Ramallah	856	205,448	362,445	156,997	76
9	Jerusalem	345	324,105	431,866	107,761	33
10	Bethlehem	659	132,090	224,575	92,485	92
11	Hebron	996	390,272	738,310	348,038	89
	Total	5653	1,810,309	2,972,060	1,161,751	64

ArcGIS10.5 software was used for digitizing the Palestinian urban areas from the ortho-rectified mosaics of the 2 years (1997 and 2016). This process has taken a long time, and it was costly, but it gave accurate and reliable results. All Palestinian urban areas (built-up areas) in the West Bank were digitized as polygons, including cities, towns, villages, refugee camps, and khirbats (a small community with less than 100 inhabitants). Israeli settlements were digitized from the aerial photographs separately, because their existence in the occupied West Bank was illegal according to the United Nations resolutions.

Buildings in the mosaic for the years 1997 and 2016 were digitized as blocks, especially in the central business district areas and old cities, villages, and refugee camps. Buildings in the old cities, villages, and refugee camps in Palestine are attached, and roads are typically seen as narrow. Only isolated scattered large buildings were digitized separately.

### Land-use/Land-cover Figuring of the West Bank Using Satellite Imagery

The Supervised image classification approach (maximum likelihood classifier) was used for the land-cover/land-use Figuring of the West Bank, mainly for the derivation of urban areas from the two Landsat images. The West Bank area was clipped from the larger Landsat images of 1997 and 2016, and a false color composite image was produced using green, red, and near infrared wavebands. These bands were the best for classifying the images of the West Bank, because they showed weaker correlation factors (Ghodieh 2000). Only ten main classes were used for the image classification (built-up areas, vegetables and crops, bare rocks, water, rocks and natural vegetation, forests and bushes and unimproved grass, olives, and other trees, plowed lands, bare bad lands, and bare bad lands<sup>2</sup>). These classes were aggregated into only three groups (built-up

areas, agricultural lands including three classes: vegetables and crops, olives and other trees, plowed lands, non-agricultural lands including six classes: bare rocks, bare bad lands, bare bad lands<sup>2</sup>, forests and bushes and unimproved grass, and rocks and natural vegetation, while the class of water is not included because it represented a very small area in the West Bank (0.1 km<sup>2</sup>), and the Palestinian part of the Dead sea was not included). Bare rocks, bare bad lands, and bare bad lands 2 were given the same color on the classified images.

## Results and Discussion

Distribution of built-up areas for the two study years was derived from the aerial photographs. Results of the localities digitizing for each governorate in the West Bank are shown in Table 2.

Table 2 shows that the overall growth in the built-up area between the years 1997 and 2016 was 519.97 km<sup>2</sup> or 176%. This was because of the establishment of the Palestinian Authority, which took the civil responsibilities from the Israeli occupation authorities in Areas A and B. Before the arrival of the Palestinian Authorities, the Israeli occupation created obstacles for the Palestinians, and it was difficult for the Palestinians to get enough licenses to build their houses or institutions. The Palestinian Authority offered facilities for the Palestinians, and any Palestinian could get a building license within 3 to 6 months. Most new houses in the rural localities and towns were built on agricultural lands, and those houses mostly consisted of one or two floors only. So, urban expansion in the rural localities was mainly horizontal. On the contrary, urban expansion in the major cities such as Nablus and Ramallah was vertical.

Tables 4 and 5 show that area of other land-use/land-cover classes derived from satellite images has changed in

**Table 2** Built-up areas change in the West Bank Governorates between the years 1997 and 2016 derived from high-resolution aerial photographs (km<sup>2</sup>)

	Governorate	1997	2016	Change (km <sup>2</sup> )	Change %
1	Jenin	29.80	92.97	63.17	212
2	Tulkarem	18.83	50.89	32.06	170
3	Tubas	5.08	23.48	18.40	362
4	Qalqilia	9.03	26.24	17.21	191
5	Salfit	9.69	21.59	11.90	123
6	Nablus	22.35	90.02	67.67	303
7	Jericho	6.91	28.80	21.89	317
8	Ramallah	51.66	111.53	59.87	116
9	Jerusalem	52.42	74.41	21.99	42
10	Bethlehem	25.44	62.14	36.70	144
11	Hebron	64.65	233.76	169.11	262
	Total	295.86	815.83	519.97	176
	Israeli settlements	83.77	148.74	64.97	77.56

the same period. On the one hand, area of agricultural lands (vegetables and field crops, olives and other trees and plowed land classes) has an overall increase of 145 km<sup>2</sup> or 9.07%. This increase came from the vegetables and crops and plowed land classes, while the area of olives and other trees decreased. On the other hand, area of non-agricultural lands (bare rocks, rocks and natural vegetation, forests, bushes and unimproved grass, bare bad land, and bare bad lands2 classes) have an overall decrease of 522 km<sup>2</sup> or 14.12%.

Table 2 also shows that the percentage of growth in the built-up area for all governorates except East Jerusalem governorate is more than 100%. Percentage of growth of built-up area in East Jerusalem is the lowest (42%), because it was difficult for the Palestinian citizen to get a building license in the city. In order to get a license, it takes more than 5 years, and it costs 20,000 US dollars. In most cases, Israeli occupation authorities rejected the license requests (Tafakje 2001). Israeli settlements have grown between 1997 and 2016 by 77.56%, but it is worth mentioning that the area of influence of the settlements exceed their geographical area.

Figure 2 shows that the Palestinian urban areas in the West Bank were concentrated in the western half, while the eastern half of the West bank was characterized by sparse localities. The physical characteristics of the West Bank to a great extent controlled the spatial distribution of the Palestinian localities, and these characteristics were topography, climate, and soil fertility. Israeli settlements were built after 1967, and the Israeli occupation authorities selected their sites carefully to control well the West Bank lands and people. They built the settlements on tops of hills and mountains, around Jerusalem holy city and in the Jordan Valley.

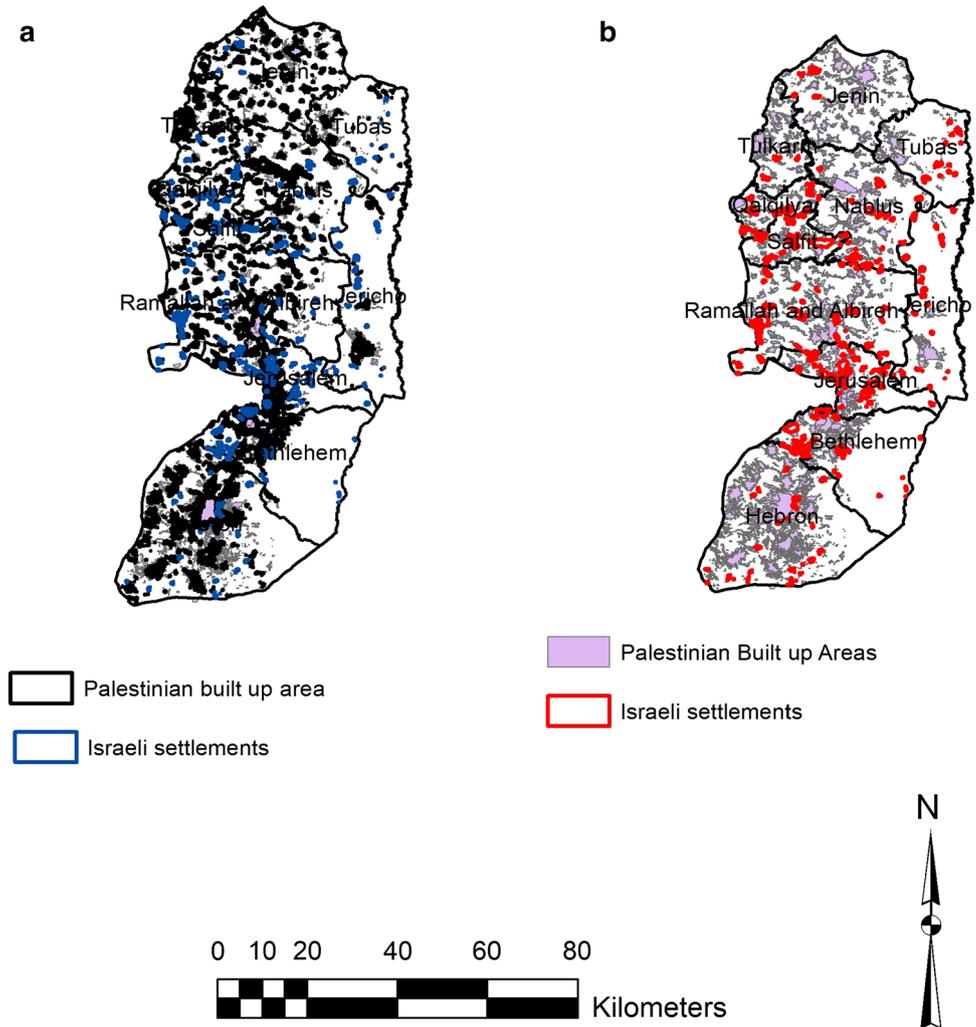
The West Bank can be divided into four physical zones: the semi-coastal zone, the mountain zone, the eastern slope zone, and the Jordan valley zone (Fig. 3).

The semi-coastal zone extends from the far northwest to the West Bank (Jenin governorate), as well as to the far southwest of the West Bank (Hebron governorate). Elevations of this zone increase gradually from less than a hundred meters in the west, to around 500 m above the mean sea level heading eastward (Google Earth Pro). It is characterized by plenty of rain (about 500 mm/year) ([www.pmd.ps](http://www.pmd.ps)), fertile soil, moderate climate, and heavy agricultural activities, because it is subjected to the marine effects of the Mediterranean Sea. These positive characteristics have encouraged people to settle in this zone. Hundreds of localities which depend on agriculture to earn their living exist in this region. But, after the Israeli occupation built the segregation wall which penetrated the zone from the north to the south, people began to leave the area and settle in the relatively larger cities such as Ramallah and Nablus, and some left Palestine to the Gulf States, USA, Canada, Australia, and Europe.

The second topographic zone is the mountains. This zone represents the backbone of the West Bank, and extends from the mid-north (Jenin) to the mid-south (Hebron). Its elevations range from 500 m on the upper western and eastern slopes, to more than 1000 m above sea level in the Hebron Mountains (Google Earth Pro). This region is characterized by a dense population and includes hundreds of Palestinian localities. The reason for the high population density is high rainfall (600–700 mm/year), moderate temperature, fertile soil, and the existence of intermediate plains. Localities in this region are mainly located either on the hill tops and mountains, or close to the intermediate plains and springs.

The third zone is the eastern slopes. This region extends from the far northeast to the far southeast of the West bank.

**Fig. 2** **a** Palestinian built-up area and Israel settlements in 1997; **b** Palestinian built-up area and Israel settlements in 2016



Its elevations range from 500 m in the upper eastern slopes, to 0 m above the mean sea level in the lower eastern slopes. It is characterized by steep slopes, little rainfall (200–400 mm/year) ([www.pmd.ps](http://www.pmd.ps)), relatively high temperatures, steep valleys, poor thin soil, and sparse vegetation cover. These characteristics have negatively affected the population density in the region. Only small localities exist in this region.

The fourth zone is the Jordan Valley. This region extends from the far northeast to the far southeast of the West Bank, along the Jordan River. Its elevations range from 0 m in the eastern part of the region, to 350 m below the mean sea level in the south (Google Earth Pro). It is characterized by very low average rainfall (100–200 mm/year), hot temperatures in summer which exceeds 40 °C ([www.pmd.ps](http://www.pmd.ps)), large areas of bad lands, and limited areas of alluvial agricultural plains. These characteristics have affected the population density negatively as well. The main locality in the region is the city of Jericho, and other localities which are of smaller sizes.

The result of the supervised image classification for the years 1997 and 2016 is shown in Fig. 4. Classification accuracy assessment for the two image dates is made. A confusion matrix is created where a number of pixels correctly assigned to each classification class and those misassigned to other classes were arranged in rows and columns relating allotted pixels in the classification image to a reference data extracted from high-resolution aerial photographs and large-scale maps. Four accuracy calculations were generated from a confusion matrix of the two classified images: overall accuracy, producer accuracy, user accuracy, and kappa co-efficient of agreement. Result of accuracy assessment is shown in Table 3.

The lowest accuracy was for rocky lands and built-up areas classes (82.9% and 81.7%), because these two classes are highly spectrally overlapped. The rest of the classes achieved an accuracy of more than 85%.

It is obvious from Fig. 4 that the urban areas and agricultural lands are concentrated in the western and the central axis of the West Bank, while the eastern axis

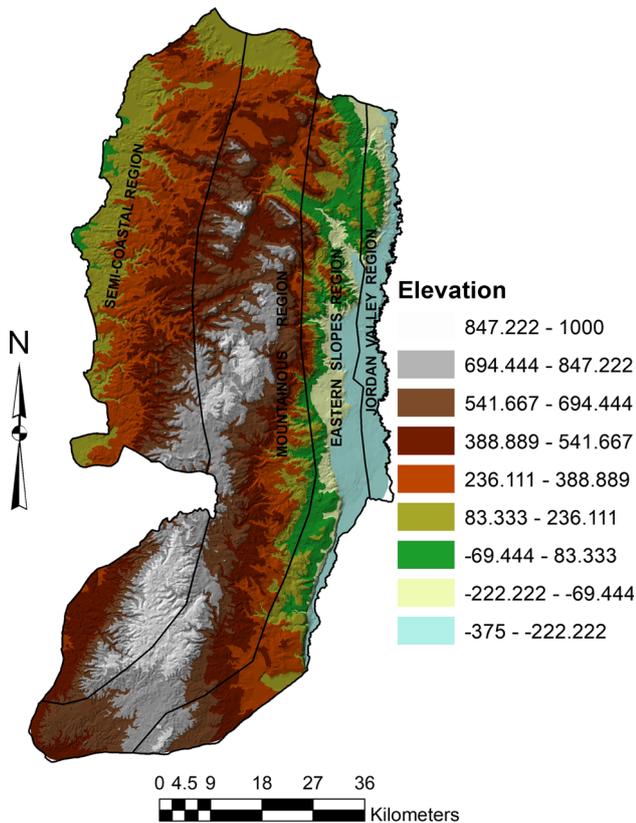


Fig. 3 Topographic regions of the West Bank

(except the city of Jericho) is characterized by scattered and small urban areas. This is mainly due to the physical characteristics of the study area. The eastern slopes, as shown on the classified image, are dominated by rocks, barren lands, bad lands, and sparse natural vegetation cover (Tables 4, 5, 6).

The geographical land-use distribution and change, particularly changes in the built-up area and agricultural lands, is due to many factors, mainly the facilities that the Palestinian Authority offered the Palestinian people, the population growth during the study period, and the geopolitical status of the West Bank.

### Effects of the Geopolitical Status in the West Bank on Urban Expansion

As mentioned earlier, the West Bank is divided into three fragmented geopolitical areas according to the Oslo Interim Agreement signed by the Palestinian Liberation Organization (PLO) and Israel in September 1993. According to that agreement, the Palestinians are allowed to construct their buildings in areas A and B without prior permission from the Israeli occupation authorities, but for area C, which represents the majority of the West Bank area, the Palestinians have to get prior permission from the Israeli

occupation to construct their buildings. This situation has affected the urban expansion in these three areas. Geoprocessing tools using the ArcGIS 10.5 software were used to predict this effect. In order to estimate the area of the built-up areas for each governorate and relate it to the geopolitical areas A, B, and C, governorates were exported and separated, and then built-up areas of the two dates were clipped by each governorate and overlaid by the geopolitical map using the geoprocessing tool 'intersect' which was used for built-up area estimation in areas A, B, and C as shown in Table 7.

Table 7 shows that the total change in Palestinian built-up area between 1997 and 2016 in the three geopolitical areas (excluding East Jerusalem city) is 484.15 km<sup>2</sup> or 176.21%. More than 70% of this change is in area A and area B. All Israeli settlements exist in area C, and so, they are under the full control of Israeli occupation.

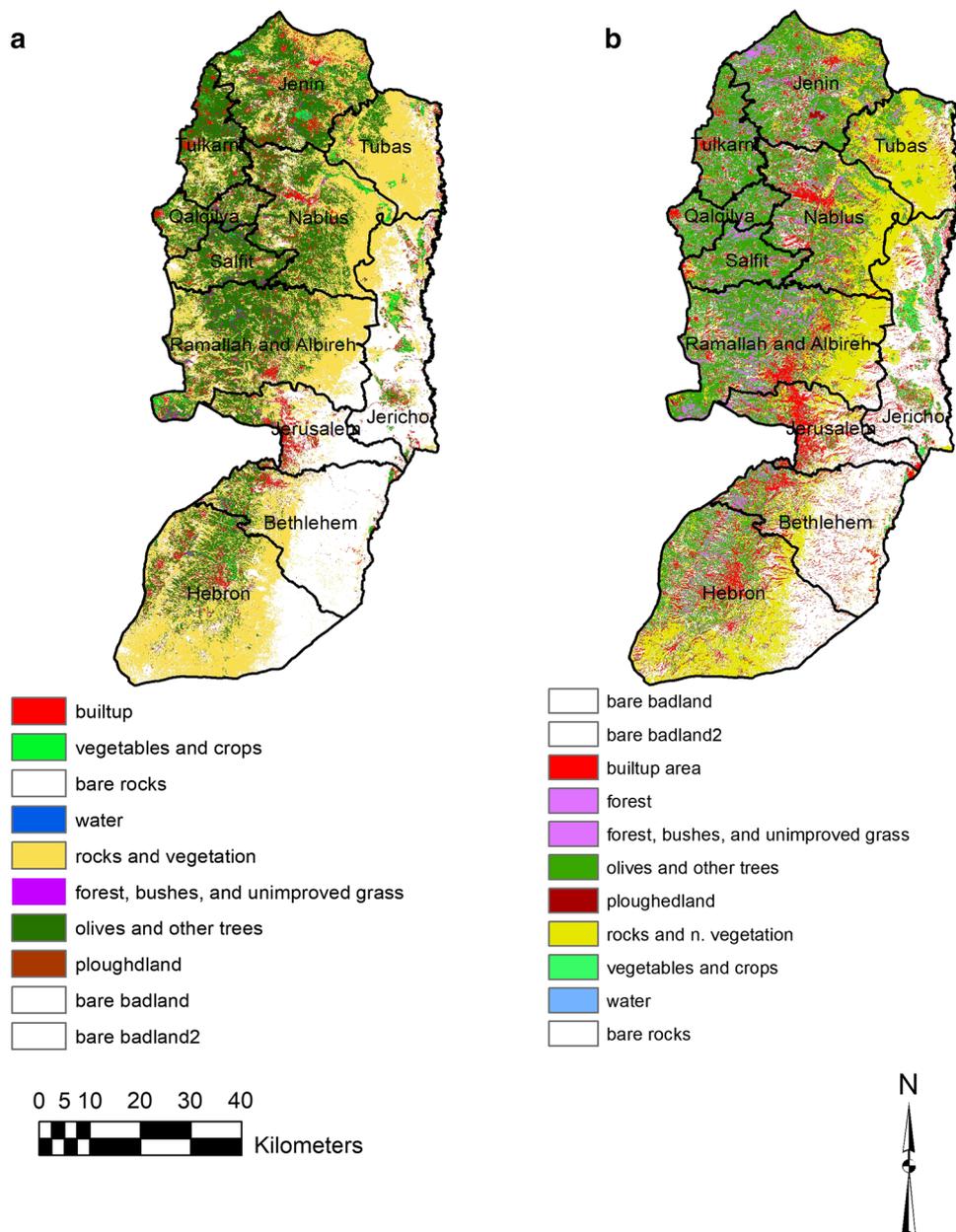
Most built-up areas in all West Bank governorates (except Jerusalem governorate) exist in area A and area B, because the Palestinian Authority (not Israeli occupation authorities) is responsible for issuing buildings licenses. There is no A area in Jerusalem governorate, because after 1967 war East Jerusalem city has been annexed to Israel by Israeli occupation authorities. Built-up areas in the Jerusalem governorate are distributed in area B and area C. Built-up areas in area C represent either small rural villages or Bedouin small houses and tents spreading on large surface areas. Bedouin houses and tents mainly spread on the eastern slopes of Nablus, Ramallah, Jerusalem, Bethlehem, and Hebron.

Table 8 shows that the built-up area in the area C represents the lowest percentage (20.9% for the year 1997, and 26.1% for the year 2016), although area C represents 61% of the West Bank area. Also, the built-up area in the area A for the year 1997 represents the highest percentage (42.8%), while it is represented by 36.3% in the area B for the same year. This is due to the fact that the Palestinian Authorities paid more attention to the cities as opposed to the rural areas (all cities lie in area A, and most villages lie in area B). In 2016, the built-up area in area B became the highest (37.7%), while it represented 36.2% in area A. This was due to the migration of some people from the cities to the rural suburbs, as well as because of the extremely high price of lands in these cities.

### Effects of Urban Expansion on Agricultural Lands in the West Bank

Due to the fact that the Palestinians do not control all their lands in the West Bank, they only can build their houses and other constructions in Areas A and B without restrictions imposed by the Israeli occupation authorities. Palestinian constructions in area C without prior permission

**Fig. 4** Land-use/land-cover classification **a** 1997 and **b** 2016



**Table 3** Classification accuracy assessment of the two image dates

Accuracy type	Classification accuracy of the 1997 image (%)	Classification accuracy of the 2016 image (%)
Overall accuracy	87.7	91.3
Producer accuracy	87.0	91.2
User accuracy	87.6	91.7
Kappa coefficient	86.0	90.0

from Israeli occupation authorities are considered illegal. Between the years 2000 and 2007, Israeli occupation authorities issued orders to demolish 4993 Palestinian houses in area C, and they only gave 91 building licenses in the same period. On the other hand, Israeli occupation authorities gave 18,472 building licenses to Israeli settlers in area C in the same period (The Palestinian Information Center-Wafa 2008). The Palestinians were forced to build their houses on agricultural lands in areas A and B. ArcGIS processing tools were used to estimate the built-up areas on these agricultural lands for the years 1997 and 2016. A land-use map of the West Bank was overlaid by the built-up area maps of the years 1997 and 2016, and the

**Table 4** Area in km<sup>2</sup> under various land-use/land-cover classes, 1997–2016

	Land cover/land use	1997	2016	Change (km <sup>2</sup> )
1	Built-up areas	357 <sup>a</sup>	734 <sup>a</sup>	377
2	Vegetables and crops	118	280	162
3	Bare rocks	242	402	160
4	Water	0.1	0.1	0
5	Rocks and natural vegetation	1690	1152	– 538
6	Forests, bushes, and unimproved grass	353	337	– 16
7	Olives and other trees	1468	1393	– 75
8	Plowed land	12	70	58
9	Bare bad land	193	655	462
10	Bare bad lands <sup>2</sup>	1223	633	– 590
	Total	5651.1	5651.1	

<sup>a</sup>Built-up areas included, in addition to the Palestinian localities, Israeli settlements, because it is not possible to exclude them from the image classification. The total area of Israeli settlements in the West Bank for the year 1997 was 83.77 km<sup>2</sup> or 1.48% of the West Bank surface, and 148.73 km<sup>2</sup> or 2.63% for the year 2016. If these settlements were excluded, the Palestinian built-up area for the year 1997 becomes 273.23 km<sup>2</sup> or 4.83% of the West Bank area, and 585.27 km<sup>2</sup> or 10.36% for the year 2016

**Table 5** Aggregated land-cover classes (km<sup>2</sup>) derived from satellite images for the years 1997 and 2016

	Land cover	Area of 1997	Area of 2016	Change	Change %
1	Built-up area	357	734	377	105.61
2	Agricultural lands	1598	1743	145	9.07
3	Non-agricultural lands	3696	3174	– 522	– 14.12
		5651.0	5651.0	0.00	

These changes in land cover/land use vary from one governorate to another

geoprocessing tool ‘intersect’ is used to estimate the built-up area on different land-use types. Table 9 shows the built-up area on different land types.

Table 9 shows that 285.33 km<sup>2</sup> of houses and other buildings were built on valuable agricultural land (field crops and orchards) between 1997 and 2016, because the Palestinians were unable to plan their urban activities on the ground, especially in area C.

## Conclusion

Results of the study showed that estimation of the built-up area using high-resolution aerial photographs and moderate-resolution satellite data is highly correlated. Using remote satellite sensing data for the built-up area estimation can be reliable, which in turn saves time and cost (result agreement is more than 99% for the year 1997 and 77% for the year 2016). Geographically, urban areas in the West Bank are concentrated in the western region, while the eastern region of the West Bank is characterized by sparse localities because of the hard physical characteristics of this region. Built-up area in the West Bank has increased between 1997 and 2016, from 274.75 to

758.9 km<sup>2</sup>, of which 73.87% is in area A and area B, and 26.13 in area C. Built-up areas in area C are concentrated in the eastern slopes topographical zone and represent small rural villages and Bedouin simple houses and tents. This urban expansion has taken place at the expense of agricultural land, where 285.33 km<sup>2</sup>, or 63% of the total urban expansion was on field crops and orchards. Area C is under the control of the Israeli occupation and building license issuance is very complicated. The Palestinians are forced to build houses without getting licenses from the Israeli authorities, which puts their houses under the constant threat of destruction. On the other hand, Israeli occupation authorities give facilities for Israeli settlers in the West Bank to build houses in area C in the West Bank (all Israeli settlements exist in area C). Israeli settlements area in the West Bank have increased from 83.77 km<sup>2</sup> in 1997, to 148.73 km<sup>2</sup> in 2016, but it is worth mentioning that the influence of these settlements on the Palestinians is much more than their geographical area. Palestinians cannot use their land and farms of olives and orchards near Israeli settlements for security reasons.

The study also showed that there is no area A in East Jerusalem governorate, and the governorate recorded the lowest percentage of urban and population growth, because

**Table 6** Land-use/land-cover area estimation of the West Bank governorate derived from satellite images for the years 1997 and 2016, including Israeli settlements

Governorate	Land cover	Area of 1997	1997 (%)	Area of 2016	2016 (%)	Change (km <sup>2</sup> )	Change %
Jenin	Built-up area	57.0	9.78	68.0	11.68	11.0	19.3
	Agricultural lands	299.0	51.29	310.0	53.17	11.0	3.68
	Non-agricultural lands	227.0	38.93	205.0	35.16	- 22.0	- 9.70
	Total	583	100	583	100		
Tulkarem	Built-up area	23.0	9.35	33.0	13.47	10.0	43.48
	Agricultural lands	149.0	60.57	163.0	66.26	14.0	9.39
	Non-agricultural lands	74.0	30.08	50.0	20.7	- 24.0	- 32.43
	Total	246	100	246	100		
Tubas	Built-up area	12.0	2.99	27.0	6.73	15.0	125.0
	Agricultural lands	57.0	14.21	67.0	16.71	10.0	17.54
	Non-agricultural lands	332.0	82.80	307.0	76.56	- 25.0	- 7.53
	Total	401.0	100	401.0	100		
Qalqilia	Built-up area	15.0	8.77	17.0	9.94	2.0	13.33
	Agricultural lands	94.0	54.97	113.0	66.08	19.0	20.21
	Non-agricultural lands	62.0	36.26	41.0	24.52	- 21.0	- 33.87
	Total	171.0	100	171.0	100		
Salfit	Built-up area	13.0	6.40	22.0	10.84	9.0	69.23
	Agricultural lands	116.0	57.14	127.0	62.56	11.0	9.48
	Non-agricultural lands	74.0	36.46	54.0	26.6	- 20.0	- 27.03
	Total	203.0	100	203.0	100		
Nablus	Built-up area	42.0	6.99	83.0	13.81	41.0	97.62
	Agricultural lands	244.0	40.60	229.0	38.10	- 15.0	- 6.15
	Non-agricultural lands	315.0	52.41	289.0	48.09	- 26.0	- 8.25
	Total	601.0	100	601.0	100		
Jericho	Built-up area	33.0	5.57	65.0	10.98	32.0	96.97
	Agricultural lands	49.0	8.28	80.0	13.51	31.0	63.27
	Non-agricultural lands	510.0	86.15	447.0	75.51	- 63.0	- 12.35
	Total	592.0	100	592.0	100		
Ramallah-al Bireh	Built-up area	51.0	5.96	104.0	12.16	53.0	103.92
	Agricultural lands	322.0	37.62	336.0	39.25	14.0	4.35
	Non-agricultural lands	483.0	56.43	416.0	48.60	- 67.0	- 13.87
	Total	856.0	100	856.0	100		
Jerusalem	Built-up area	38.0	11.01	92.0	26.74	54.0	142.11
	Agricultural lands	42.0	12.17	49.0	14.20	7.0	16.67
	Non-agricultural lands	265.0	76.81	204.0	59.13	- 61.0	- 23.02
	Total	345.0	100	345.0	100		
Bethlehem	Built-up area	24.0	3.64	80.0	12.16	56.0	233.33
	Agricultural lands	53.0	8.04	56.0	8.50	3.0	5.66
	Non-agricultural lands	582.0	88.32	523.0	79.34	- 59.0	- 10.14
	Total	659.0	100	659.0	100		
Hebron	Built-up area	49.0	4.92	143.0	14.33	94.0	191.83
	Agricultural lands	172.0	17.26	209.0	20.98	37.0	21.51
	Non-agricultural lands	775.0	77.82	644.0	64.67	- 131.0	- 16.90
	Total	996.0	100	996.0	100		

**Table 7** Built-up area in A, B, and C areas in the West Bank for the years 1997 and 2016

Area type	Built-up area 1997 (km <sup>2</sup> )	%	Built-up area 2016 (km <sup>2</sup> )	%	Change (km <sup>2</sup> )	Change (%)
A	117.61	42.81	274.30	36.14	156.69	133.22
B	99.59	36.25	286.35	37.73	186.76	187.53
C	57.55	20.94	198.25	26.13	140.70	244.48
Total	274.75	100	758.90	100	484.15	176.21

**Table 8** Built-up area (km<sup>2</sup>) in A, B, and C areas in the West Bank Governorates for the years 1997 and 2016

Governorate	Built-up area in area A		Built-up area in area B		Built-up area in area C		Total built-up area	
	1997	2016	1997	2016	1997	2016	1997	2016
Jenin	21.83	54.88	6.60	21.50	1.35	12.43	29.78	88.81
Tubas	4.08	17.37	0.58	2.09	0.37	2.99	5.03	22.45
Tulkarem	9.24	18.48	8.32	20.14	1.26	10.78	18.82	49.40
Qalqilia	2.54	3.67	5.08	10.00	1.46	9.00	9.30	22.67
Salfit	2.13	3.62	6.09	10.17	1.48	5.64	9.70	19.43
Nablus	9.52	26.88	12.23	49.42	0.60	6.72	22.35	83.02
Jericho	4.98	23.23	0.23	0.38	1.53	4.88	6.74	28.49
Ramallah	18.93	27.80	22.53	57.46	5.31	20.40	47.77	105.66
Jerusalem	0.00	0.00	11.84	18.09	22.39	37.25	34.23	55.24
Bethlehem	15.03	25.15	6.75	16.10	3.66	12.10	25.44	53.35
Hebron	29.34	73.50	18.40	81.10	18.11	75.57	63.85	230.17
Total	117.61	274.71	99.59	286.41	57.55	197.78	274.75	758.90
Total %	42.8	36.2	36.3	37.7	20.9	26.1		

**Table 9** Built-up areas on different land-use types

Land use	Built-up area (km <sup>2</sup> ) for 1997	Built-up area (km <sup>2</sup> ) for 2016	Change (km <sup>2</sup> )
Field crops	22.61	111.79	89.18
Natural forest	0.86	3.96	3.1
Orchards, mainly olives	61.00	257.15	196.15
Planted forest	0.32	0.89	0.57
Shrubland	49.92	213.30	163.38
Total	134.71	587.09	452.38

the Israeli occupation authorities measured and imposed obstacles on the daily life of the Palestinians, in particular, with regard to the houses license issuance.

Ending the Israeli–Palestinian conflict and establishing peace between the two nations in the region according to the United Nations resolutions is the only way to solve the implications and consequences of the complex geopolitical status in the urban sector of the West Bank.

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