Chapter 13
Urban Land Use Change Analysis and Modeling: A Case Study of the Gaza Strip

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Abstract Analysis of land use and land cover change is of prime importance for understanding the ecological dynamics resulting from natural and human activities, and for the assessment and prediction of environmental change. The population of the Gaza Strip will have grown to more than 2.4 million by 2023 all of whom are forced to live within an area of some 365 km^2. This growth in population will lead to an increase in land demand, and will far exceed the sustainable land use capacity. The Gaza Strip is a relatively small area in which land use planning has not kept up with land development. Continued urban expansion and population growth in the future will place additional stress on land cover, unless appropriate integrated planning and management decisions are taken immediately. Decision-makers need further statistics and estimation tools to achieve their vision for the future of the Gaza Strip based on sound, accurate information. This study combines the use of satellite remote sensing with geographic information systems (GISs). The spatial database was developed by using six Landsat images taken in 1972, 1982, 1990, 2002, 2013 and 2014, together with different geodatabases for those years. Five past trend scenarios were selected for simulation to be completed by the year 2023 using the Land Change Modeler in the Idrisi Terrset software. These different scenarios, one of which takes into account the damage incurred during the 2014 War, try to cover the possible variations in areas and spatial distribution resulting from changes in land use. As an average over the five scenarios, by 2023 the projected urban area will have increased to 206.24 km^2 or 57.13% of the Gaza Strip.

Keywords Land use and land cover change · Scenario · Urban · Land change modeler

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1 Introduction

Understanding, predicting and analyzing land use and cover change is enormously important for future planning. One of the major factors affecting land use in the Gaza Strip is rapid population growth, one of the most significant issues in Palestinian society today. According to the Palestinian Central Bureau of Statistics (PCBS), with the recent growth rates of 3.44% in mid-2013, and 3.41% in mid 2014 (PCBS 2014) the population of the Gaza Strip will have grown to over 2.4 million by 2023. This area already has one of the highest population densities in the world with an estimated 3,956 persons/km^2 in 2006. This figure is even higher in the Gaza governorate (around 6,834 persons/km^2) where most of the population is concentrated. Another serious problem in Gaza is urban sprawl. The number of housing units in the Gaza Strip increased from 116,445 in 1997 to 147,437 in 2007 (PCBS 2012). Many human and natural factors have increased pressure on land use in this region, resulting in deteriorating quality and quantity of land (Abuelaish and Camacho 2016). Urbanization leads to increasing pressure on natural ecosystems (Taubenbock et al. 2012; Haas and Ban 2014) and brings with it soil, water and air pollution (Duh et al. 2006; Ren et al. 2003).

The Gaza Strip has been a theatre of conflict for decades. Each of these conflicts has left its mark, and a significant environmental footprint has developed in the Gaza Strip over time (UNEP 2009). The population growth rate and the urban expansion it drives affect the whole region. In general people prefer to live close to the urban facilities and infrastructures, usually found in the center of the residential areas, and to avoid the dangerous areas. The Gaza Strip has been directly involved in many wars, most recently in 2008, 2012 and 2014. The 2014 war was the most destructive in terms of buildings and infrastructure. The Israeli offensive against the Gaza Strip was launched on 8th July and continued until 26th August 2014. It left devastation all across this region, ranging from damage to complete destruction of thousands of homes. Post-war reconstruction is likely to exacerbate the normal urban growth rate, so adding a greater burden on this already congested country.

Several monitoring techniques, such as Remote Sensing, are very useful for gathering the data required for land use change assessment, urban planning, urban sprawl and other environmental issues. Land use changes must be monitored at suitable intervals in order to update the knowledge required to support decision making. Monitoring of land use and land cover requires the support of two parameters: spatial resolution and temporal frequencies (Curran 1985; Janssen 1993; Hualou et al. 2007). Modeling can be defined within the context of geographic information systems (GISs) as occurs whenever GIS operations attempt to emulate processing in the real world, at one point in time or over an extended period (Goodchild 2005; Paegelow et al. 2013). GIS models go beyond simply evaluating the future and are used to assess different scenarios, on the basis of the historical data retrieved from multiple resources. Scenarios have emerged as useful tools to explore uncertain futures in ecological and anthropogenic systems (Sleeter et al. 2012). Scenarios typically lack quantified probabilities (Nakicenovic and Swart 2000;

Swart et al. 2004), functioning instead as alternative narratives or storylines that capture important elements about the future (Nakicenovic and Swart 2000; Peterson et al. 2003; Swart et al. 2004). Alcamo et al. (2008) define scenarios as "descriptions of how the future may unfold based on 'if-then' propositions." Scenarios provide a structured framework for the exploration of alternative future pathways, and are used to assist in the understanding of possible future developments in complex systems that typically have high levels of scientific uncertainty (Nakicenovic and Swart 2000; Raskin et al. 1998). Plausible scenarios generally require knowledge of how drivers of change have acted to influence historical and current conditions (Sleeter et al. 2012).

This study aimed to analyze urban growth and monitor the spatial and temporal changes from 1972 to 2014 within five past trend scenarios using a model based on GIS techniques and remote sensing data. One of these scenarios takes into account the damage caused by the 2014 war. Scenarios are proposed to 2023, which can be helpful for planning decisions to be taken in the Gaza Strip within this timeframe. These decisions will be have an enormous impact on the future of environmental issues and urban development.

This paper begins by presenting the study area of the Gaza Strip. We then explain the methodology, including data processing, land change analysis, simulation and modeling of the study area before and after the 2014 war in the Gaza Strip. Finally, we present the results, discussion and conclusions.

2 Study Area and Dataset

2.1 Study Area

The Gaza Strip is a narrow area on the Mediterranean coastal plain. It is approximately 41 km long, and from 6 to 12 km wide, with a total area of 365 km^2. It shares a 12 km border with Egypt to the southwest and is surrounded by Israel to the east and north (the rest of the Strip—51 km of borders), as shown in Fig. 1. The Gaza Strip has a temperate climate, with mild winters (about 13 °C) and hot summers with frequent droughts (high 20 s °C). Average rainfall is about 300 mm a year (MOAg 2013). The terrain is flat or rolling, with dunes near the coast. In terms of topography the Gaza Strip slopes gradually downwards from east to west with the land surface elevation varying between 10 m above sea level in the west to 110 m above sea level in the east.

In 1948, the Gaza Strip had a population of less than 100,000 people (Ennab 1994), however by 2007, it had risen sharply to around 1.4 million (Census 2007). The total population in 2014 was estimated to be in excess of 1.79 million and, at the end of 2015, about 1.82 million inhabitants, distributed across five Governorates (PCBS 2015), of whom almost 1.3 million were UN-registered refugees. Gaza City, which is the biggest governorate, has some 625,824 inhabitants. The other two

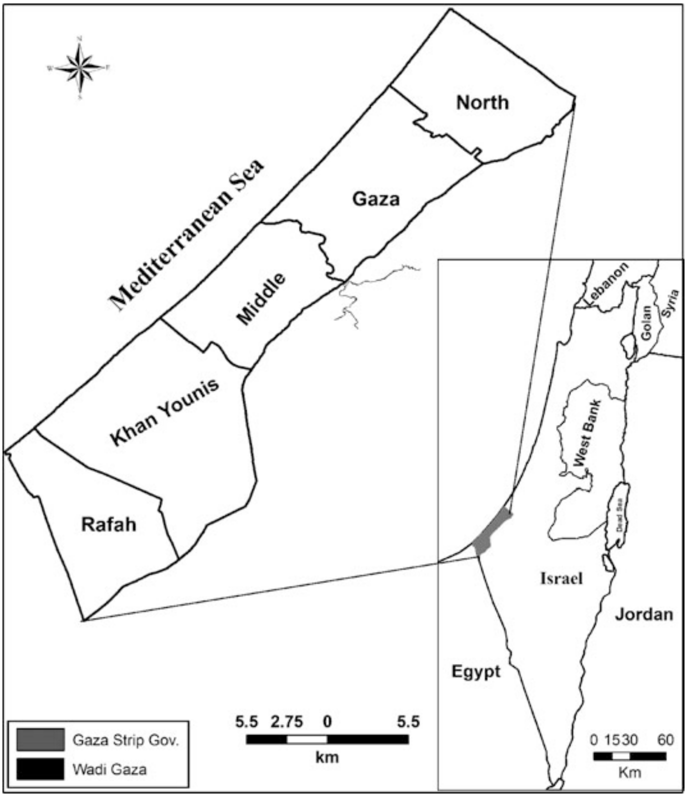


Fig. 1 Location on the Gaza Strip

main governorates are Khan Younis and Rafah in the southern part of the Gaza Strip, which have 341,393 and 225,538 inhabitants, respectively. There is also the Northern Governorate, with a population of about 362,772, and the Middle Governorate, which has 264,455 inhabitants. The smallest governorate in terms of area is the Middle Governorate, with 55.19 km^2. This is followed by Rafah (60.19 km^2), the Northern Governorate (60.66 km^2), and Gaza (72.44 km^2). The largest governorate is Khan Younis with an area of 111.61 km^2, as shown in Fig. 1.

Agriculture is the economic mainstay of the employed population, and nearly three quarters of the land area is under cultivation. On the Gaza coastal plain the original Saharo-Sindian flora has been almost completely replaced by farmland and buildings. Gaza has six main vegetation zones: the littoral zone along the coast, the stabilized dunes and blown-out dune valleys, the Kurkar, alluvial and grumosolic soils in the northern part, the loessial plains in the east, and three wadi (valley) areas (UNEP 2006).

2.2 Dataset

The spatial database has been produced using the historical Landsat images from 1972, 1982, 1990, 2002, 2013 and 2014, as shown in Table 1. The images were rectified from the aerial photos for 2007 using Erdas Imagine 2013. Generalized digitalization was used to build the urban GIS database using ArcGIS 10.2; interpretation was mainly visual, and both supervised and unsupervised classifications were used for more control and interpretation. The cell size of the entire dataset was converted to 15 × 15 meters. The database was validated before starting the analysis by tracking data with high resolution aerial photographs taken before and after a particular year. As no aerial photographs were available for the last year, we validated some points that were in doubt using the UNITAR database.

For the purposes of this research, we considered the whole Gaza Strip area as suitable for agriculture and classified the land into two classes: urban and agricultural areas (non-urban areas). Some other land uses and land covers in the study area were also considered as agricultural in this study.

On 20th November 2014, the UNRWA, UNDP and the Ministry of Public Works and Housing (MOPWH) announced the conclusion of their assessment of the damage caused to housing during the 2014 War, which they had conducted jointly over a two month period. 6,761 residential buildings were totally destroyed (including more than 11,000 housing units), 3,565 were severely damaged and 4,938 units were moderately damaged, as shown in Table 2. The UNITAR/UNOSAT

Table 1 Landsat data used in this study

Sensor	Row	Data type
Landsat MSS	188/38	22/10/1972
Landsat 3 TM	188/38	13/08/1982
Landsat 5 TM	174/38	11/06/1990
Landsat 7 ETM+	175/38	05/07/2002
Landsat 8	175/38	25/06/2013
Landsat 7 ETM+	175/38	24/09/2014
GIS dataset of UNOSAT/UNITAR	Geodatabase	Field Survey, October/2014

Table 2 Buildings damaged during the 2014 War

	Destroyed	Severely Damaged	Moderately Damaged	Total Structures Affected	Crater Impact
North	1,253	761	1,000	3,014	1,702
Gaza	1,963	1,127	1,378	4,468	1,765
Middle	809	406	683	1,898	553
KhanYounis	1,749	898	1,379	4,026	1,549
Rafah	987	373	498	1,858	1,904
TOTAL	6,761	3,565	4,938	15,264	7,473

Source UNITAR/UNOSAT (2014)

created geodatabases based on field work and high resolution satellite images. All images used to analyze the conflict were taken by the Pleiades satellites operated by Airbus Defense and Space, which provide 50 cm resolution images (UNITAR/UNOSAT 2014). The UNITAR/UNOSAT Geodatabase contains a total of 22,745 sites with crater impacts or some form of damage to housing after attacks during the war.

3 Methodology and Practical Application to the Datasets

The flow chart in Fig. 2 shows the methods used in the research reported in this paper, including the definition and creation of a database using remote sensing and GIS, land changes analysis, proposal and testing of explanatory variables, modeling and scenarios development of scenarios in the Gaza Strip.

3.1 Land Use Model and Data

3.1.1 Land Change Analysis

The chronological series of LUC maps was analyzed to detect changes. A quantitative assessment of category-wise land use changes in terms of net changes, swap, gains, losses and total changes (Eastman 2012) was extracted from several pairs of data, and the results are shown in maps and statistics. The change analysis was performed specifically between two images from 1972, 1982, 1990, 2002, 2013 and 2014 to understand the transitions in land-use classes over the years. A multiple regression line was created to predict the future urban area, and statistical values for the changes occurred in the area were represented on a scatter diagram.

3.1.2 Proposal and Testing of Explanatory Variables

Five static drivers were selected to simulate and predict the future urban area in 2023. The first driver is the distance from the main and regional roads in 2013, given that the population prefers to buy and live in houses overlooking the roads, which are also considered good investments. The second driver is elevation, because people prefer high locations which are considered to be safe from floods during rainfalls and have a more temperate climate in summer. The third driver is the distance from the urban area in 2013, since people prefer to live close to well-established urban areas with better infrastructure and services, which are safer during Israeli military attacks. The fourth driver is the 1 km wide buffer zone along

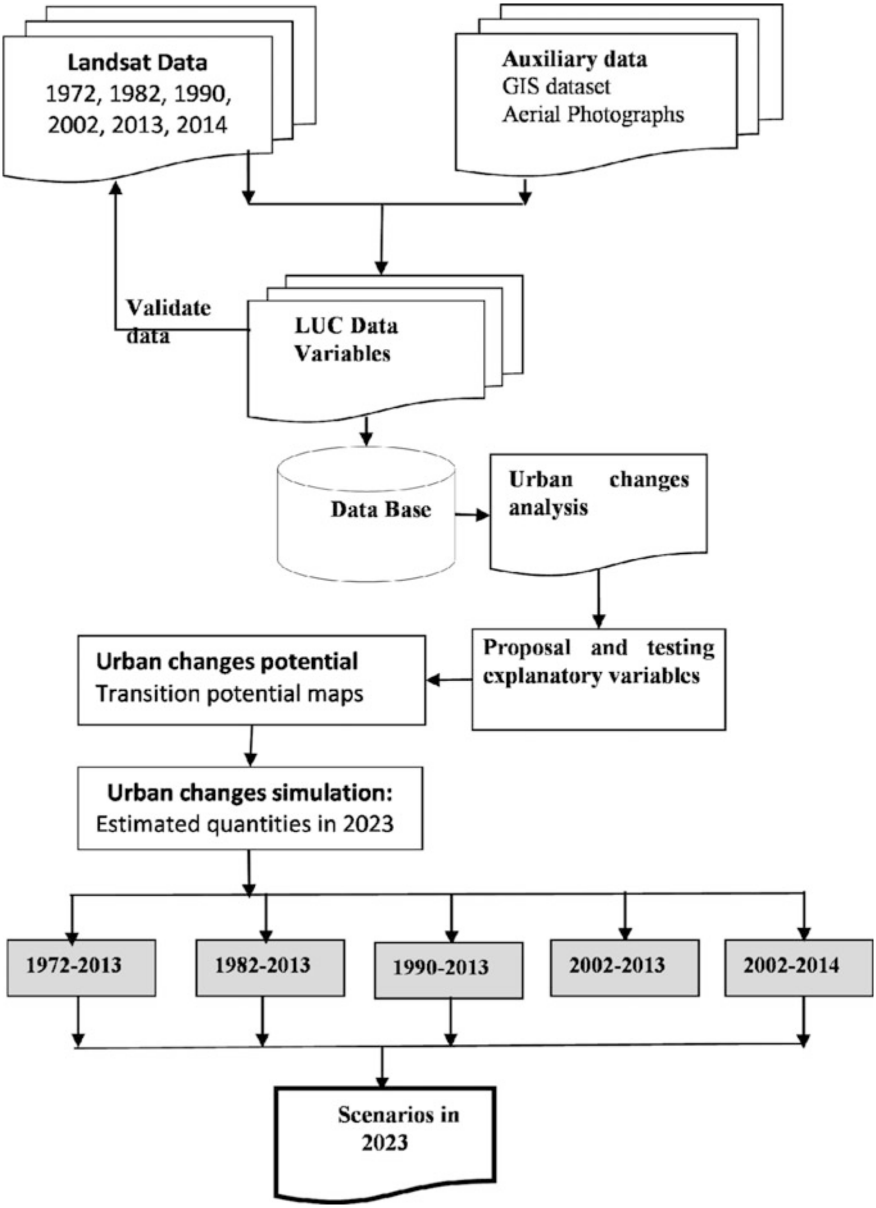


Fig. 2 Methodology flow chart of land-change analysis, potential and simulation

the border between the Gaza Strip and Israel. This is a restricted area which people are forbidden to enter. The fifth driver is the buildings destroyed during the 2014 War. It is only used in the 2002–2014 scenario.

The quantitative measure of the influence of the variables can be obtained using Cramer's V. A high Cramer's V value indicates that the variable has good explanatory potential, but does not guarantee a strong performance since it cannot take into account the mathematical requirements of the modeling approach or the complexity of the relationship. However, a very low Cramer's V value is a good indication that a variable can be discarded (Eastman 2012). The Cramer's V values for these drivers for all the calibrated periods were Elevation 0.142, Roads 0.169, Distance to built-up areas 0.707 and Border buffer zone 0.230.

We noticed that the Cramer's V values were similar for all the calibrated periods using the same latest land cover map (2013). Cramer's V values for the calibrated period (2002–2014) were also very similar, and its fifth key driver of "buildings destroyed during the war" obtained a value of 0.0294.

Even though the "buildings destroyed during the war" variable could be discarded because it has a very low Cramer's V value of 0.0294, we decided to include it because it is a key driver for reconstruction.

The results from the categories revealed that the distance to built-up areas and away from the border buffer zone were the main drivers for all predictions.

3.2 Methodology for Modeling and Scenario Development

In order to project the urban area in 2023, we selected a GIS model in Idrisi Terrset software called the Land Change Model (LCM). This model is used to analyze land cover change, empirically modeling its relationship to explanatory variables and projecting future changes (Eastman 2012).

3.2.1 Land Change Potential: Transition Potential Maps

To predict the change, each land use transition must be modeled empirically on maps called transition potential maps. These maps are used together with driver maps. A collection of factors are obtained from these drivers by the Natural Log Transformation. The Natural Log Transformation is effective in linearizing distance decay variables (e.g., proximity to roads) (Eastman 2012).

The transition potential maps are in essence potential maps for each transition in LCM. A collection of transition potential maps is organized within an empirically evaluated transition sub-model that has the same underlying driver variables. A transition sub-model can consist of a single land cover transition or a group of transitions that are thought to have the same underlying driver variables. These driver variables are used to model the historical change process. The transition potential maps are obtained by Multilayer Perceptron (MLP) in LCM. The MLP option can run multiple transitions and undertakes the classification of remotely-sensed imagery through the artificial neural network multi-layer perceptron technique. It uses an algorithm to set the number of hidden layer nodes.

MLP automatically evaluates and weights each factor and implicitly takes into account the cor-relations between the explanatory maps (Eastman 2012).

3.2.2 Land Change Simulation: The Estimated Quantities

The Markov transition area matrix is based on land-use changes without drivers that are produced within the Markov chain from two different dates. This matrix results from the multiplication of each column in the transition probability matrix by the number of cells for the corresponding land use in the last image for the year 2013 or 2014.

Markov chain analysis is used to calculate the estimated quantities in 2023 within the urban data for all the scenarios (1972–2013), (1982–2013), (1990–2013), (2002–2013) and (2002–2014) up to 2023.

The MARKOV module computes the transition areas matrix and the transition probability matrix by cross tabulation between LUC categories from two maps (t0 to t1), which reflect data from the calibration stage, to project the estimated changes and persistence at the simulation stage (t1 to T). The estimation to T is based on the number of time periods between t0 and t1 and the number of time periods between t1 and T, respecting in any case the same time units. A more detailed description of the MARKOV matrix can be found in the Idrisi Terrset Help System and also in Mas et al. (2014). The Markov chain analysis is one of the most widely used stochastic approaches in ecological and environmental modeling (Paegelow and Camacho 2008).

Linear regression was used to compare the results of the Markov chain data, i.e. an approach which uses the historical relationship between a dependent variable and one or more independent variables (the year and the population) to predict the future values of the dependent variable, in this case urban areas. The multiple linear statistical regression was used for simulation of the built-up area using the Enter method to enter all variables for the year 2023 at the same time on the basis of the urban area in 1972, 1982, 1990, 2002, 2013 and 2014. The growth rate and other statistics were calculated using Microsoft Excel.

3.2.3 Land Change Simulation: The Scenario

The five scenarios are simulated in a single model to predict the likely urban area in 2023. The LCM model uses an a priori identical Multi-Objective Land Allocation (MOLA) to solve the concurrences between different uses or transitions, in which the MOLA works only once. This process is based on the choice of the most suitable pixels, i.e., those with the greatest change potential in the change potential maps (ranked from high to low). Through the Markov matrix, the MOLA creates a list of host classes (categories that will lose area, in rows) and claimant classes (categories that will gain area, in columns) for each host. The land allocation process is conducted for all the claimant classes in each host class. In this way it solves the conflicts based on a minimum-distance-to-ideal-point rule using the weighted ranks, and the final result is the overlay of each host class reallocation (Eastman et al. 1995; Mas et al. 2014).

4 Results

4.1 Land Change Analysis of Chronological Series of LUC Maps

The results showed a drastic change in land cover and the growth of the urban area between 1972 and 2014, as shown in Fig. 3, when many agricultural areas were urbanized. This has happened in a largely unplanned, somewhat chaotic fashion, so revealing the need for land-use managers and city planners to understand future growth and plan further developments. Over this period urban areas have grown continuously, whereas non-urban (agricultural) areas have shrunk at similar rates, as shown in Table 3.

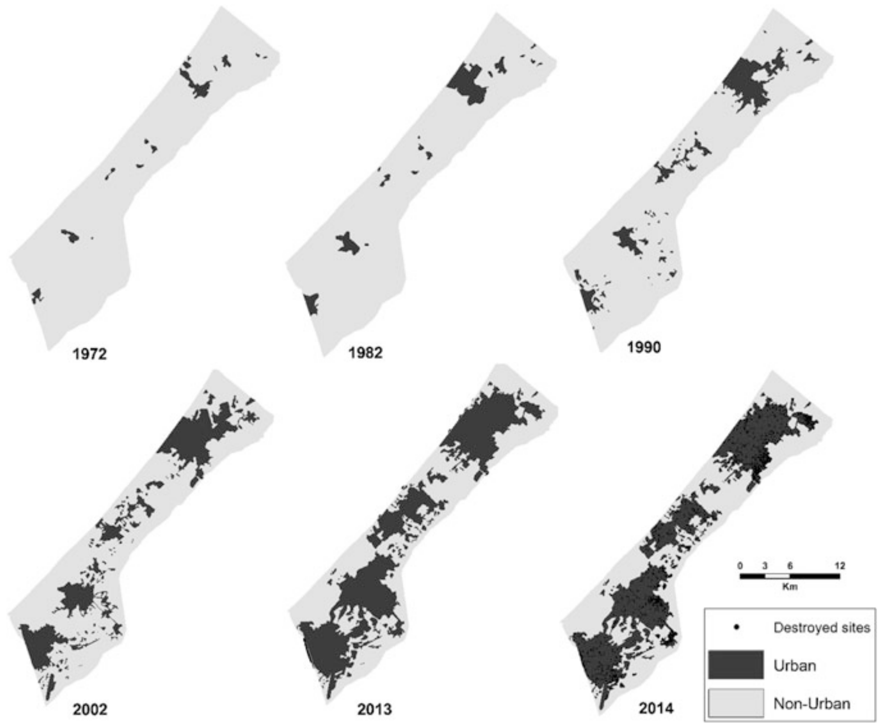


Fig. 3 Urban areas from 1972 to 2014

Table 3 Urban and non-urban areas from 1972 to 2014

Year	Urban, km^2	Urban, %	Non-urban km^2	Non-urban, %
1972	10.94	3.00	349.06	96.96
1982	25.29	7.00	334.71	92.98
1990	46.88	12.80	313.12	86.98
2002	100.23	27.40	259.77	72.16
2013	166.29	46.20	193.71	53.81
2014	164.80	45.78	195.20	54.22

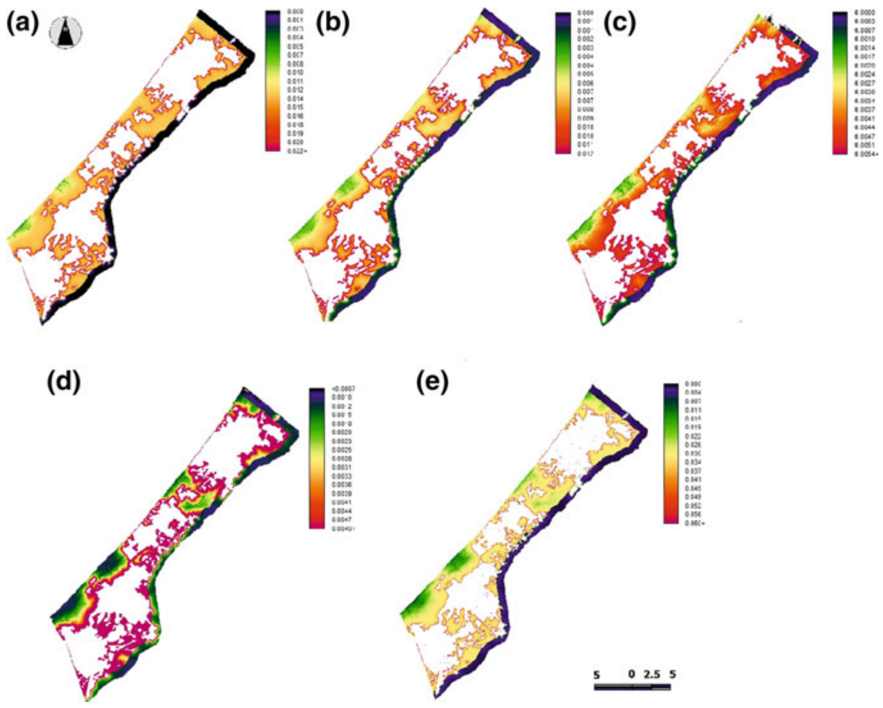


Fig. 4 MLP transition potential map from non-urban to urban area for LCM for **a** (1972–2013), **b** (1982–2013), **c** (1990–2013), **d** (2002–2013), **e** (2002–2014)

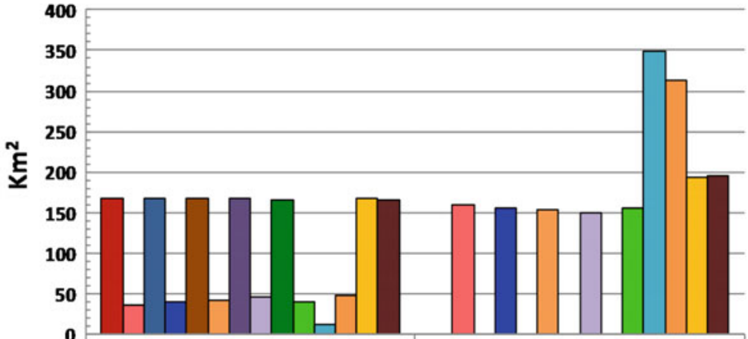
4.2 Transition Potential Maps

The MLP Neural network was used to obtain the transition potential map for the transition from Non-Urban to Urban area, as shown in Fig. 4a to Fig. 4e, based on the real transition over the various calibration periods (1972, 1982, 1990, and 2002) to 2013, and (2002) to 2014. The high transition potential values are located around the built-up area with the biggest population density (low distance). Figure 4 shows the transition potential maps for the five scenarios.

4.3 The Estimated Quantities

The Markov transition area matrix (Fig. 5) shows areas (km^2) in which a transition between two classes will have taken place by 2023. Rows represent land use in the calibration period in 2013 or 2014 and columns represent land use in the simulation year 2023, based on the five scenarios.

A multiple regression analysis shows the historical relationship between the urban area, the year and the population (independent variables) to project the future of the urban area for the year 2023, i.e. 240.79 km^2, using the Enter method. The results of the stepwise method show that population growth has had a direct effect on urban expansion. The significant number is around zero and the urban area is 246.5 km^2.



	Urban	Non-Urban
Urban 1972-2013	166.29	0
Non-Urban 1972-2013	36.09	158.56
Urban 1982-2013	166.29	0
Non-Urban 1982-2013	38.61	156.03
Urban 1990-2013	166.29	0
Non-Urban 1990-2013	40.67	153.97
Urban 2002-2013	166.29	0
Non-Urban 2002-2013	46.06	148.59
Urban 2002-2014	165.55	0
Non-Urban 2002-2014	39.18	155.86
1972	10.94	349.06
1990	46.88	313.12
2013	166.29	193.71
2014	164.80	195.20

Fig. 5 Transition area matrix for the estimation of urban areas in the five scenarios by the year 2023, and 1972, 1982, 1990, 2002, 2013 and 2014 in area (km^2)

The adjusted R2 is therefore 0.98, meaning that predicted values statistically demonstrate a high ‘goodness of fit’. The stepwise regression equation can be expressed as follows:

$$Y = -1,016.667 + 0.501\mathbf{X_1} + 9.985 * 10^{-5}\mathbf{X_2}$$

The diagram in Fig. 6 shows a comparison between six past trend scenarios. The first five scenarios are the Markov chains from (1972–2013), (1982–2013), (1990–2013), (2002–2013) and (2002–2014) to 2023; and the sixth one is the regression line to 2023 depending on the basic data using the Enter method, which gave areas of 202.35, 204.89, 206.95, 212.32, 204.70 and 240.79 km^2, respectively.

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4.4 Simulation Maps: Scenario to 2023

The results of the simulation in the five scenarios varied according to the Markov chains, i.e. (1972–2013), (1982–2013), (1990–2013), (2002–2013) and (2002–2014) were 202.35, 204.89, 206.95, 212.32 and 204.70 km^2, respectively, as shown in Fig. 7.

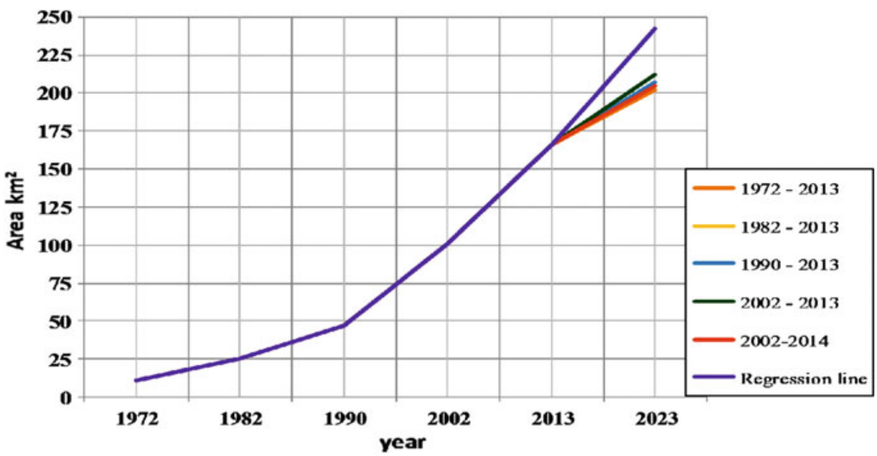

Fig. 6 The plot lines for urban area in km^2 from 1972 to 2023, Markov chain (1972–2013), Markov chain (1982–2013), Markov chain (1990–2013), Markov chain (2002–2013), Markov chain (2002–2014), and regression analysis

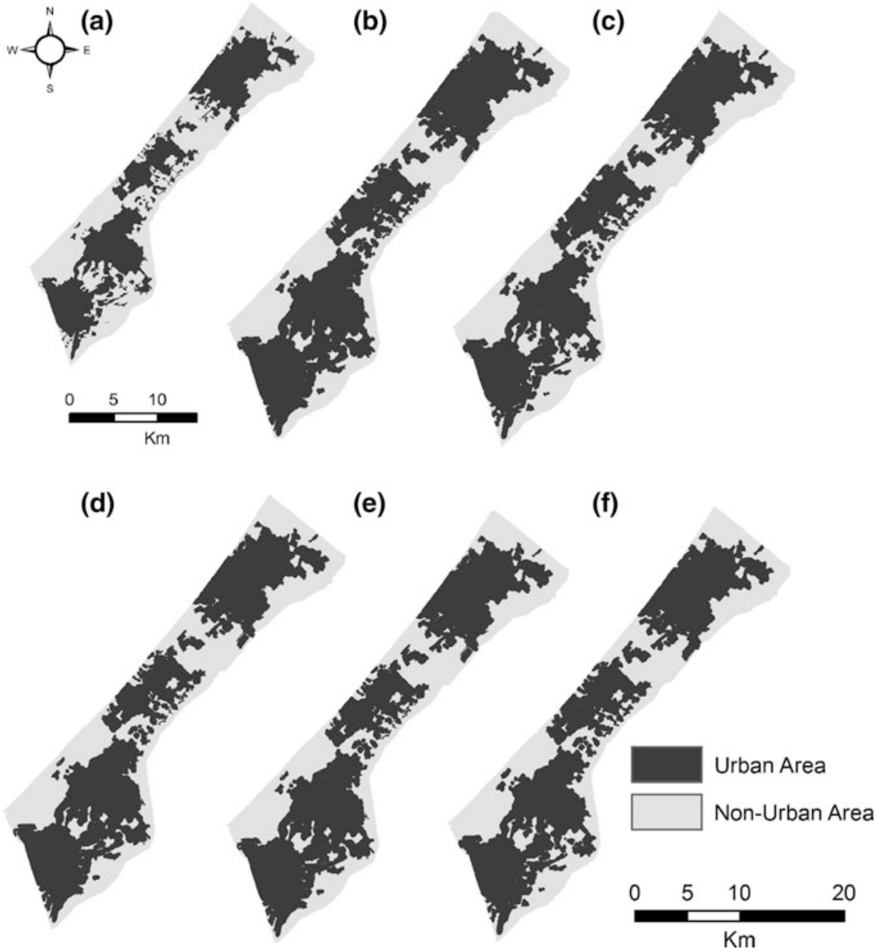

Fig. 7 **a** Real map 2013 and simulated maps for the year 2023 as results of **b** Scenario (1972–2013), **c** Scenario (1982–2013), and **d** Scenario (1990–2013), **e** Scenario (2002–2013), **f** Scenario (2002–2014)

The results of the simulation (individual results for each scenario and the average of all five) are presented in Fig. 8 and Table 4, which show an increase in urban areas and a decrease in non-urban areas between 1972 and 2014. The predicted urban and non-urban areas for 2023 for the periods (1972–2013), (1982–2013), (1990–2013), (2002–2013), and (2002–2014 after the war) are presented in Table 4.

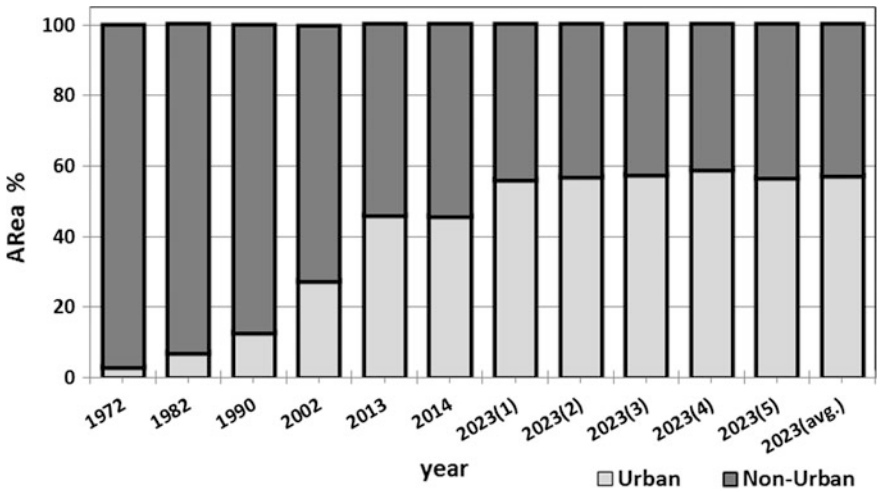

Fig. 8 Increase in urban areas and decrease in non-urban areas from 1972 to 2023

Table 4 Area and percentage of urban and non-urban areas in all scenarios

Scenario	Year	Urban, km^2	Urban, %	Non-urban, km^2	Non-urban, %
1972–2013	2023 (1)	202.37	56.21	157.63	43.79
1982–2013	2023 (2)	204.89	56.91	155.11	43.09
1990–2013	2023 (3)	206.95	57.49	153.05	42.51
2002–2013	2023 (4)	212.34	58.98	147.66	41.02
2002–2014	2023 (5)	204.70	56.86	155.30	43.14
Average	2023 (avg.)	206.25	57.29	153.75	42.71

5 Discussion

The overall results of the five LCM scenarios analyze and simulate land-use changes in the Gaza Strip. The results of the past trend scenarios for spatial distribution per area in 2023 presented both differences and similarities in the allocation of urban area. We discovered an inverse relationship between the predicted area by 2023 and the length of the calibration period, in that the longer the calibration period the smaller the growth in urban area predicted. The urban areas for 2023 predicted by the calibration periods (1972–2013), (1982–2013), (1990–2013) and (2002–2013) were 202.35, 204.89, 206.95 and 212.32 km^2. The calibration period (2002–2014), which showed an increase in urban area to 204.7 km^2 by 2023, is slightly exceptional due to the fact that it includes the 2014 War.

The results for calibration periods 2002–2013 and 2002–2014 have a high "goodness of fit", because they both obtained values close to the regression analysis value (240.79) used to measure statistical best fit values, while the values for the other scenarios were substantially further away from the regression analysis value.

As a percentage of the total area of the Gaza Strip, the scenarios predict that between 56.21 and 58.98% will be urbanized by 2023. The data analysis shows an increase in the urban area from 10.9 (1972) to 25.3 (1982), 46.9 (1990), 100.2 (2002), 166.3 (2013) and 206.24 km^2 in 2023, the average area predicted by the various simulations for the whole Gaza Strip (i.e. around 57.13% of the total). While the decrease in Agricultural areas (Non-Urban Area) was caused by an increase in population growth rate and a lack of management and future planning.

Figure 9 illustrates the increase in the rate of growth in urban area as a percentage of the total area of the Gaza Strip for each time period (1972–1982), (1983–1990), (1991–2002), (2003–2013), 2014 and (2015–2023), with rates of 0.40, 0.7584, 1.35, 1.83, −0.39 and 1.44% from 1972 to 2023, which implies a positive relationship with the rate of population growth.

The population density for the whole of the Gaza Strip will therefore have in-creased from 4,661.5 inhabitants per km^2 in 2013 to 6,704.3 inhabitants per km^2 in 2023. However, in the urban areas the increase will be from 10,231.1 inhabitants per km^2 in 2013 to 11,865.1 inhabitants per km^2 in 2023. Table 5 shows that urban expansion is positively correlated with population growth in the Gaza Strip, which already has one of the highest population densities in the world.

The Palestinian economy in the Gaza strip grew in line with the Israeli economy over the period from 1972 to 2000. There was a dramatic rise in the Palestinian standard of living from 1972 until the eruption of the first Intifada (uprising) in 1987. The main reason for improved living standards was the opening of the rapidly expanding Israeli job market to Palestinian workers (Swirski 2008). The situation continued until the signing of the 1993 Oslo Accords. From 1994 to 2000 there were huge urban projects and a great deal of investment leading to urban expansion (Abuelaish and Camacho 2016).

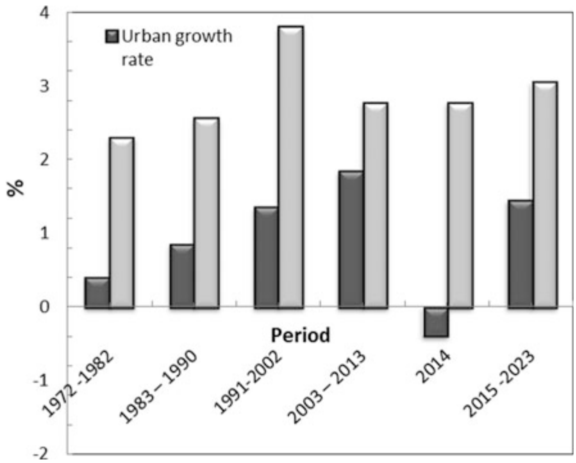

Fig. 9 Population and urban growth rates for the different periods, from 1972 to 2023

Table 5 Increase in urban area, population number and population density from 1972 to 2023

Year	Population No.	Area (km^2)	% Area	Population Density No./area	Actual Pop. Density
1972	393,800	10.9	3	1,078.9	36,128.4
1982	511,115	25.3	7	1,400.3	20,202.2
1990	642,814	46.9	12.8	1,761.1	13,706.1
2002	1,182,908	100.2	27.4	3,240.8	11,805.5
2013	1,701,437	166.3	46.2	4661.5	10231.1
2014	1,760,037	164.80	45.78	4822.0	10679.84
2023	2,447,054	206.24	57.13	6704.3	11865.1

Many of the Palestinian workers in Israel, considered the mainstay of the Palestinian economy have been unemployed since the conflicts in 2000. In 2007 an economic blockade was started around the Gaza Strip, which for a short period prevented urban expansion from continuing at the same rate as before. From 1972 to 1994 urbanization was more vertical than horizontal, a situation that was reversed thereafter (Abuelaish and Camacho 2016).

Effects of the 2104 War

According to the Ministry of Public Works and Housing (MOPWH), an estimated 2,000 tons of cement for residential construction purposes enter the Gaza Strip daily. This would give a monthly figure of around 44,000 tons. Ground floors require about 0.54 tons of cement per m2, while all other floors require 0.21 ton/m^2; the average area of buildings in the Gaza Strip is 150 m^2. Of the 11,000 housing units destroyed during the war, 5,990 had ground floors, and there were 5,189 on other floors. Hence, 648,643.5 tons of cement would be required for reconstructing all the destroyed housing units. At the current supply rate of 44,000 tons a month, reconstruction would therefore take 15 months. This is an ideal scenario in which allowing cement to enter the country and receiving funds to rebuild the residential housing units are essential factors.

According to the temporary agreement for the Gaza Reconstruction Mechanism (GRM) in Shelter Cluster Palestine (February, 2016), 1,107,519 tons of cement have entered the Gaza Strip since October 2014. Around 44% has been used for residential purposes, i.e. 487,308.36 tons. This is enough cement to rebuild 6,016 ground-floor apartments or 15,470 apartments above ground-floor level.

Table 6 shows the completed housing units, those in progress, funded, and awaiting funds from donors as of February 2016, according to Shelter Cluster Palestine. Around 83% of the destroyed housing units are still awaiting funds from donors, which means that a significant amount of the cement must be being used to build new housing units in different places. These construction materials are not only being used to reconstruct destroyed buildings but also to cover normal urban growth and supply building companies everywhere. The black market is playing a major role in selling cement outside the GRM as a result of shortages in the system. This has allowed people to build new houses without a license. Since the war, people prefer to buy housing units in the center of urban areas and to live in

Table 6 Repairs and reconstruction of the housing units damaged and destroyed during the 2014 War

	# Units*	Completed	In progress	Funded	Gap
Totally destroyed	11,000	937	591	3,479	5,993
Severe damage	6,800	2,034	3,027	1,097	642
Major damage	5,700	119	1,075	1,747	2,759
Minor damage	147,500	69,428	9,936	10,060	58,076

Source Shelter Cluster Palestine (February, 2016)

apartment buildings. This is because town centers are considered safer and new building on urban land with planning permission tends to be very expensive.

According to the 2007 Census, there were 241,873 housing units in the Gaza Strip, and according to the projected number of households and housing units in the Gaza Strip using the hypothesis of average number of households per year (PCBS 2009), about 15,529 housing units were required in 2015 and 16,284 in 2016. The amount of cement that entered the Gaza Strip in the previous period was enough for normal urban growth but there were problems for reconstructing the destroyed buildings due to a shortage of donor finance. Around 10–15% of the destroyed housing units were reconstructed in the 15 months between September 2014 and February 2016. International donors at the Cairo Donor Conference on 12th October 2014 pledged over USD 5.4 billion to support the plan to rebuild the Gaza Strip.

Reconstruction of the Gaza Strip is a priority for the Palestinian Authority, and all the destroyed buildings during war 2014 are entitled to financial support. The reconstruction efforts however depend on financial support from the donors, and also on Israel allowing construction materials to enter the Gaza Strip. Since the shortage of building materials due to the blockade affects both reconstruction efforts and natural urban growth, if the blockade ended, the Gaza Strip would return to its previous natural urban growth rate. The fact is however that there is no guarantee that Israel will not repeat past behavior and launch new wars on the Gaza Strip, and there is no expectation of the economic blockade coming to an end soon.

This study tries to answer questions about the future of the Gaza Strip and the impacts on its environment. This information is useful for decision-makers and politicians, who are regularly faced with questions about the complicated situation in the Gaza Strip as a result of its weak economic resources, and the lack of donor support from countries concerned by other conflicts such as in Syria. Most of the houses destroyed during the war belong to poor people who are waiting for financial support to rebuild their houses. Many urban areas were destroyed during the war and their reconstruction would be harder without modeling exercises such as the one presented here.

6 Conclusions

This paper presents, analyses, evaluates, and simulates urban expansion for the years 1972 to 2014 to 2023, using the historical free Landsat data and the free UNITAR/UNOSAT Geodatabase for the areas attacked during the 2014 war. These simulations are based on the continuity of observed past trends and are not exact predictions. Instead they are plausible scenarios of a future state assuming the maintenance of macro-political and social conditions.

The following conclusions were drawn from the results of this research in which we performed a simulation of urban growth in the Gaza Strip for the year 2023 using five scenarios and the Land Change Modeler:

- Around 57.13% of the Gaza Strip will be urban land.
- Around 10–15% of the buildings and infrastructure damaged during the war had been rebuilt and returned to their previous state of natural growth by February 2016.
- The amount of building materials entering the Gaza Strip must be increased and additional support must be given to the people who lost their houses during the 2014 War.
- There is an inverse relationship between the predicted urban area for 2023 and the length of the calibration period.
- Urbanization in the Gaza Strip is increasing dramatically because of natural population growth. This is placing more stress on agricultural areas, causing soil erosion and impairing water quality and quantity.
- Urban planners should take into account that in the near future the three main urban areas will merge into one.
- Urban sprawl increases over time at the expense of agricultural land, above all due to an increase in population.
- The reduction in agricultural land in the Gaza Strip and the pressure placed on natural resources will contribute to local and global climate change.

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References

Abuelaish B, Camacho Olmedo MT (2016) Scenario of land use and land cover change in the Gaza Strip using Remote Sensing and GIS models. J: Arab J Geosci. http://dx.doi.org/10.1007/s12517-015-2292-7

Alcamo J, Kok K, Busch G, Priess J (2008) Searching for the future of land: Scenarios from the local to global scale. In: Alcamo J (ed) Environmental futures: the practice of environmental scenario analysis. Elsevier, Amsterdam, The Netherlands

Curran PJ (1985) Principles of remote sensing. In: Remote sensing today. longman scientific & technical, London

Duh JD, Shandas V, Chang H, George LA (2006) Rates of urbanisation and the resiliency of air and water quality. Sci Total Environ 400(1–3):238–256

Eastman JR (2012) Idrisi Selva Tutorial. Clark University, Worcester, MA, USA

Eastman JR, Jin W, Kyem W, Toledano P (1995) Raster procedures for multi-criteria? Multi-objective decisions. Photogramm Eng Remote Sens 61(5):539–547

Ennab WR (1994) Population and demographic developments in the West Bank and Gaza Strip until 1990. UNCTAD, Geneva

Goodchild MF (2005) GIS and modeling overview. In: Maguire DJ, Batty M, Goodchild MF (eds) GIS, Spatial analysis, and modeling. Redlands, CA: ESRI Press, pp 1–18

Haas J, Ban Y (2014) Urban growth and environmental impacts in Jing-Jin-Ji, the Yangtze River Delta and the Pearl River Delta. Int J Appl Earth Obs Geoinf 30:42–55

Hualou L, Guoping T, Xiubin L, Heilig GK (2007) Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China. J Environ Manag 83:351–364

Janssen LLF (1993) Methodology for updating terrain object data from remote sensing data: the application of landsat TM Data with respect to agricultural fields. Dissertation Wa-geningen Agricultural University

Mas JF, Kolb M, Paegelow M, Camacho Olmedo MT, Houet T (2014) Inductive pattern-based land use/ cover change models: a comparison of four software packages. Environ Model Softw 51(2014):94–111. doi:10.1016/j.envsoft.2013.09.010

Nakicenovic N, Swart R (eds) (2000) IPCC special report on emission scenarios. Cambridge University Press, Cambridge, UK

Paegelow M, Camacho Olmedo MT (2008) Modelling environmental dynamics. Advances in geomatic simulations. Series environmental science. Springer, Heidelberg. ISBN 978-3-540-68489-3

Paegelow M, Camacho Olmedo MT, Mas JF, Houet T, Pontius RG Jr. (2013) Land Change Modelling: moving beyond projections. Int J Geogr Inf Sci 27(9):1691–1695. Taylor & Francis doi:10.1080/13658816.2013.819104

Palestinian Central Bureau of Statistics (PCBS) (2009) Housing Projections up to 2017

Palestinian Central Bureau of Statistics (PCBS) (2012) Census final results in The Palestinian Territory Summary (Population, Housing and Establishments Census-2007)

Palestinian Central Bureau of Statistics (PCBS) (2015) Local Communities Survey

Palestinian Ministry of Agriculture (MOAg) (2013) Unpublished material and statistical data

Peterson GD, Cumming GS, Carpenter SR (2003) Scenario planning: a tool for Cconservation in an uncertain world. Conserv Biol 17:358–366

Raskin P, Gallopin G, Gutman P, Hammond A, Swart R (1998) Bending the curve: toward global sustainability. a report to the global scenario group. PoleStar Series Report No. 8. Stockholm Environment Institute, Stockholm, Sweden

Ren W, Zhong Y, Meligrana J, Anderson B, Watt WE, Chen J, Leung HL (2003) Urbanization, land use, and water quality in Shanghai: 1947–1996. Environ Int 29(5):649–659

Shelter Cluster Palestine (2016) Palestine report, February 2016. www.ShelterCluster.org Accessed February October 2016

Sleeter BM, Sohl TL, Bouchard M, Reker R, Sleeter RR, Sayler KL (2012) Scenarios of land use and land cover change in the conterminous United States -Utilizing the Special Report on Emission Scenarios at ecoregional scales: global Environmental Change at http://dx.doi.org/10.1016/j.gloenvcha.2012.03.008

Swart RJ, Raskin P, Robinson J (2004) The problem of the future: sustainability Science and scenario analysis. Glob Environ Change 12:137–146

Swirski S (2008) The burden of occupation. The cost of the occupation to israeli society, polity and economy. Adva Center, Tel Aviv

Taubenbock H, Esch T, Felbier A, Wiesner M, Roth A, Dech S (2012) Monitoring urbanization in mega cities from space. Remote Sens Environ 117:162–176

UNEP (2009) Environmental Assessment of the Gaza Strip following the escalation of hostilities in December 2008–January 2009 United Nations Environment Programme

UNEP (2006) Environmental Assessment of the Areas Disengaged by Israel in the Gaza Strip. United Nations Environment Programme

UNITAR/UNOSAT (2014) Impact of the 2014 Conflict in the Gaza Strip, UNOSAT Satellite derived geospatial analysis