

Population and pavement: population growth and land development in Israel

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Abstract This research examines land use change in Israel—an intriguing but understudied setting with regard to population–environment dynamics. While Israel is fairly unique with regard to its combined high levels of economic prosperity *and* high population growth, this case study has relevance for developed countries and regions (like the south and southwest regions of the USA) which must balance population growth and urban development with open space conservation for ecosystem services and biological diversity. The population–land development relationship is investigated during the period from 1961 to 1995 at three spatial scales: national, regional (six districts), and local (40 localities). There is a positive correlation between population growth and land development rates at the national scale, and while remaining positive, the strength of the relationship varies greatly at regional and local scales. The variation in population–land use dynamics across scales is used to garner insight as to the importance of geography, policy and historical settlement patterns.

Keywords Land use/land cover change · Urbanization · Open space preservation · Population growth · Land use policy · Israel

Introduction

Population issues—fertility, immigration, demographic composition, and spatial distribution—have been central to Israeli public policy since the time before the

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country's establishment in 1948 (Evans 2006; Goldscheider 1996; Kanev 1957; Portugese 1998). Yet, little attention has been given in the academic literature to the environmental dimensions of population dynamics in Israel, despite the compelling anecdotal evidence that population pressures on Israel's environment are profound (Orenstein 2004; Tal 2002).

In this study, we measure the transformation of open space to built space in Israel during a period of 34 years, and analyze the relationship of this environmental change variable to population growth at three spatial scales. This spatially and temporally-informed approach allows us to address well-known conceptual challenges within the population–environment literature, including assessing (1) the direction and magnitude of the correlation between population growth and environmental impact; (2) the influence of temporal and spatial scale of analysis on this correlation, and (3) how policies may affect the relationship between population growth and environmental impact.

By virtue of choosing land use/land cover (LUCC) change as our environmental change indicator, we are able to address not only one of the most pressing environmental problems in high-density, developed nations, but also theoretical issues within the relatively new discipline of LUCC Science. The LUCC literature lacks study on the drivers of urban expansion, as opposed to the abundant scholarship that focused on deforestation, agricultural extensification, and desertification (but see Hunter et al. 2003 for an exception).

For several reasons, Israel offers an intriguing opportunity for examining population–environment interactions, in particular as these interactions impact open space availability. First, Israel is one of the most densely populated and urbanized countries in the world, and thus provides a potential glimpse into the future for many countries. Second, the country's population growth rate is higher than is typical of countries with a similar economic profile (PRB 2004), thus providing a unique example of high population growth combined with relatively high affluence.¹ Third, as more land is urbanized to meet the residential needs of a growing population with demands for larger homes, open space is being increasingly recognized as a crucial, but dwindling, resource (Kaplan 1999; Tal 2008). Issues of urban sprawl and loss of open space have thus become important policy issues in Israel, as elsewhere in the developed world (European Environment Agency 2006; Gillham 2002; McKinney 2002). Fourth, the country has high levels of biodiversity in a small area (Frankenberg 1999; Yom Tov and Mendelsohn 1988), which intensifies the ecological significance of urbanization and open space loss in Israel.

¹ Using GNI Purchasing Power Parity (PPP) as an economic indicator, Israel resembles Spain, Portugal, Greece, and Slovenia, all of which had a 2002 GNI PPP between \$17,000 and \$21,000. However, all of the latter countries have an annual rate of population increase of less than 0.1% whereas Israel's rate of annual increase was 1.6%. Countries that bore resemblance to Israel with regard to both rate of population increase and GNI PPP were Kuwait and Bahrain (Population Reference Bureau 2004).

Background

The study setting: Israel

The demographic and land use setting

In Israel, both land development (Kellerman 1993; Yiftachel 1998) and population growth (DellaPergola and Cohen 1992; Orenstein 2004; Portugese 1998; Schiff 1981) are central to national, Zionist ideology. Therefore, it is crucial to understand the political context of demography and urbanization in Israel before exploring the interaction between population growth and urban land development.

After the demographic upheavals resulting from the 1948 war (Friedlander and Goldscheider 1979), Israel's population grew from less than one million to 7.4 million in 2008. This is a 3.7% mean annualized growth rate over a 60-year period, one of the highest in the developed world (all statistics from Central Bureau of Statistics, CBS 2009). The population continues to grow at a rate of approximately 1.8% annually. Immigration has been a significant, if sporadic, contributor to population growth, adding 3.1 million people between 1948 and 2008 and accounting for ~38% of Israel's population growth. Israel has one of the highest population densities of any developed country, with 320 persons/km², or 780 persons/km² when the sparsely populated Negev desert is excluded. The total land area of country is 21,600 km². The land area of the sparsely populated Beer Sheva sub-district, which comprises the southern 60% of the country's land area, is 12,900 km² but has never accommodated more than 8% of the total population.²

Jewish population growth has consistently been a central ideological and policy focus in Israel (DellaPergola and Cohen 1992; Kanev 1957; Portugese 1998; Schiff 1981; Winckler 2008). Jewish immigration, both before and after the establishment of the state, and high fertility rates were seen by Zionist and Israeli policymakers as key to the establishment and survival of a Jewish state (Ben-Gurion 1938; Kanev 1957). Owing to a prolonged decline in the proportional representation of the Jewish population in the entire population (from 86% in 1949 to 76% in 2008, CBS 2009), there has been a growing perception among some public figures and academics of a "demographic threat" to the continuity of the country's Jewish identity (Ettinger 2003; Soffer and Bystrov 2005, 2007). This perception surfaces in public discourse as a significant influence on demographic (Portugese 1998; Winckler 2008) and spatial development policies (Evans 2006; Newman 1984).

Population distribution has also been a significant policy concern since before the founding of the state (Kellerman 1993). Land-use and population dispersal patterns reflect ideological positions expressed through government policy (Feitelson 1999; Kellerman 1993), which was partly facilitated by the fact that 93% of the land is nationalized and the country has a tradition of strong central (top-down) planning

² From the perspective of open-space preservation, it is important to note that much of the Negev Desert, while relatively unpopulated, is used extensively for military training zones. In addition, it is used for mining of minerals and is the site for repositories of solid, chemical and radioactive waste.

(Alterman 2001; Newman 1986).³ This connection was especially strong during the first three decades of the country's existence, a period characterized by a broad public consensus on national goals (Feitelson 1999; Kellerman 1993).

A major theme of population distribution policy has been the emphasis on redistribution of Israel's Jewish population away from the center of the country, where most of that population has preferred to live. Population redistribution was justified based on economic and geopolitical considerations: e.g., populating frontier regions, redistributing economic growth, and addressing perceived "demographic imbalances" in areas with Arab majorities (Evans 2006; Falah 1991; Kellerman 1993; Yiftachel 1999). In order to attract Jewish populations to the peripheral regions, incentives were offered to internal migrants in the form of subsidies as well as spacious, "ground-attached" homes (e.g., single-family homes and duplexes), which were unaffordable to many residents of the central region. The spatial growth of Arab communities, in contrast, was constrained by governmental policy (Falah 1991; Khamaisi 1993, 2004). While the emphasis on redistributing the Jewish population from the center of the country to the periphery continues as a national priority, the focus regions for development have varied over time.

With regard to form of settlement, the Labor Zionist governments from 1948 until 1977 advocated for a rural, agrarian lifestyle. In practice, this meant encouraging the establishment and settlement of agricultural, cooperative communities, and protecting farmland from development (Applebaum et al. 1989; Feitelson 1999; Newman 1986). Nonetheless, rural settlements never accounted for more than 25% of the population (Kellerman 1993). In recent years, rising land prices in the country's central area (Werczberger and Borukhov 1999), declining emphasis on farmland protection (Feitelson 1999), and rising preferences for suburb-style living have had a profound impact on spatial patterns of land development since the 1980s. While most development continues to be high density, sprawling residential communities have become an additional prominent feature on the Israeli landscape.

The environmental setting

Open space is a particularly important issue in Israel, where its conversion to built space has drastically altered the landscape (Kedar 1999; Tal 2002). This is of environmental concern for several reasons. First, the country has very high biodiversity relative to its size (Dolev and Perevolotsky 2004; Sapir and Shmida 2006) due to its unique position as a land bridge between three continents, its

³ The academic literature on planning in Israel most often refers to strongly centralized control of land use in Israel. However, there are situations and research that challenge this assumption. Prior to National Outline Plan 31 in the early 1990s, planning in Israel was sectoral rather than comprehensive (Frenkel 2004), allowing for market and/or political pressures to catalyze development in circumvention of centralized planning processes. One such example is mountaintop residential development in the Galilee in the 1980s (Carmon 1990). Another is illegal or unplanned development in multiple sectors (commercial centers, residences, storage facilities) as documented by environmental organizations and by the State Comptroller's office; development that is often approved ex-post facto by decision-making bodies. Alfasi (2006) suggests that the combination of mandated flexibility measures for planning at the local level coupled with illegal circumvention of statutory planning guidelines produces results that do not reflect official planning goals.

intense climate gradient (ranging from hyper-arid to Mediterranean), and its diverse topography (Frankenberg 1999; Yom Tov and Mendelsohn 1988). Humans have been actively modifying the landscape of Israel for over 10,000 years, and in contrast to this century's intensive urban transformations, past agricultural and grazing patterns are thought to have contributed to increasing biodiversity (Perevolotsky and Seligman 1998; Yom Tov and Mendelsohn 1988). Additional ecosystem services are provided by open space, including agricultural production, recreational and aesthetic values, flood control, pollution sinks, and more (Kaplan 1999; Sagi 2000).

Protection of open space from unplanned and/or low-density development has recently been written into statutory, long-term national development plans (Assif and Shachar 2005; Shachar 1998). Yet, several factors maintain pressure to develop open spaces, including population growth, continued interest in population redistribution schemes, and changing residential preferences toward more dispersed and spacious homes.

Local units of governance in Israel

In order to understand patterns of spatial development in Israel, a short description of local governance patterns is necessary. There are three types of localities in Israel: city, local council, and regional council (CBS 1997). Each has distinct spatial development and demographic characteristics. Cities and local councils consist of a single urban community with cities generally having a population over 10,000 (Ministry of the Interior, MoI 2003). Most of the predominantly Arab communities in Israel are administered as local councils, although a few have obtained city status.

Regional councils consist of many small, distinct, communities, geographically analogous to rural/exurban counties in the United States. The communities that fall within the boundaries of regional councils are mostly, though not entirely, Jewish. Historically, these communities were primarily agrarian (the collective “kibbutz” or semi-collective “moshav”), although over the past three decades agriculture has significantly decreased in economic importance for these communities. During this period, many “community settlements” have been established within regional councils that have no agricultural identity, with their residents tending to commute to urban centers (Kellerman 1993; Newman 1986). Community settlements within regional councils are defined as rural if their population is less than 2000 inhabitants and as urban if their population is greater than 2000 inhabitants, independent of the overall council population density (MoI 2003). Some Arab villages and Bedouin tribes fall within the administrative boundaries of regional councils (CBS 1997).

Population, environment, and land use/cover change

Demographers and environmental scientists have had a sustained interest in the relationship between population characteristics and environmental quality (Lutz et al. 2007; Pebley 1998). However, identifying the relationship between population and environmental (P–E) variables poses several conceptual and methodological challenges (Lutz et al. 2007). Four challenges facing P–E researchers include

- (1) Defining the *impact* of population growth on environmental quality (e.g., positive, negative, or neutral). Substantial debate exists as to whether population growth contributes to environmental degradation (De Souza et al. 2003; Ehrlich 1970; Hardin 1993; Harrison and Pearce 2000; Malthus 1976; Reid et al. 2005), is neutral, or improves environmental quality through innovation (Boserup 2005; Condorcet 1976; Lomborg 2001; Simon 1998).
- (2) Mapping the *causal pathway*, if one exists, by which population dynamics affect environmental variables (Moffitt 2005; Palloni 1994). The P–E relationship may be mediated by a broad range of social, political, and economic variables. Lutz and colleagues (2007) stress that successful P–E research necessitates explicitly defining the mediating variable(s) through which population is hypothesized to impact a given environmental parameter.
- (3) Quantifying the *magnitude* of the environmental impact of population growth and other demographic dynamics, has substantive implications for environmental policy e.g., energy use, air pollution, and greenhouse gas emissions (Bongaarts 1992; Cramer 1998; DeHart and Soule 2000; Dietz and Rosa 1997; O’Neill and Chen 2002; Satterthwaite 2009).
- (4) Defining the *spatial and temporal scales of analysis* of the relationship between population and environment. Investigations at different scales can lead to seemingly contradictory results. As a result, scholars studying P–E relationships emphasize the importance of carefully defining spatial and temporal scale and assuring a theoretically justifiable connection between dependent and independent variables under investigation (Axinn and Barber 2003; Entwisle and Stern 2005; Rindfuss et al. 2004; Walsh et al. 2001; Walsh et al. 1999).

Land Use/Cover Change (LUCC) provides an excellent context for investigating the aforementioned P–E challenges. LUCC science gained prominence in the analysis of global environmental change in the past few decades as the extent and magnitude of the aggregate human impact on the biosphere became increasingly clear (e.g., deforestation, proliferation of cultivated agriculture, desertification, urbanization) (Harrison and Pearce 2000; Vitousek et al. 1997). The impact of demographic change, and population growth in particular, on LUCC remains the subject of substantial debate across a variety of disciplines.

In the 1980s and 1990s, global population growth was implicated as an important factor driving LUCC, as it had been with respect to many forms of environmental change. Summing up the scientific paradigm at the time, Meyer and Turner (1992) wrote that population growth had been a preferred variable for explaining LUCC because it was both plausible and easily quantifiable, even if it was difficult to prove causation. They concluded that the role of population growth in LUCC was not in dispute, but rather, what remained unclear was its relative importance among several possible driving forces. Although population growth exhibited an association with LUCC, so did other socio-economic and political factors.

The impact of population growth on environmental change is difficult to detect for several reasons. First, as noted, its impact is assumed to function in combination with other variables including economic and policy changes, as well as

demographic changes other than population growth. Second, population growth itself may respond to feedbacks from LUCC, and it may be impacted by exogenous variables that simultaneously impact both population and LUCC. Third, large scale spatial and temporal processes may often mask those found to occur at smaller scales unless they are being explicitly investigated (Rindfuss et al. 2004).

Scholarship has also increasingly investigated intermediate variables in the P–E association. In LUCC research, for example, Bilsborrow and DeLargy (1990) find that while the aggregate impact of population growth in rural areas of developing countries is positively associated to deforestation, the mechanisms vary according to the socio-economic responses of households to dwindling supplies of cultivable land in diverse policy and institutional contexts (Bilsborrow and DeLargy 1990). Heilig (1994) considers research into the relationship between population and LUCC a “fruitless endeavor” without including consideration of intermediate variables, such as technological innovation, change of lifestyle, and political decisions.

The emerging consensus in the LUCC literature is that multiple demographic, economic, institutional, cultural, and technological factors drive LUCC and these operate synergistically (Geist and Lambin 2002; Giannecchini et al. 2007; Lambin et al. 2003; Lambin et al. 2001). Thus, rather than implicating population growth per se, environmental response to human activity is increasingly understood to be influenced by interacting factors of which population growth is but one dimension.

As with P–E research in general, all of these issues (complexity, feedbacks, temporal, and spatial scale) present significant methodological challenges (Ramanakutty et al. 2006; Rindfuss et al. 2004; Turner et al. 2007). Recommendations for addressing these challenges include (1) a careful matching of population data to the environmental dynamics they are hypothesized to impact (Lutz et al. 2007; Rindfuss et al. 2004), (2) conducting multiple case-specific studies of LUCC at a variety of study sites and spatial scales to inventory and model the range of potential drivers under varying institutional and political conditions (Lambin and Geist 2002; Mustard et al. 2003), and (3) adopting a systems-analysis approach, such that multiple drivers and feedbacks are considered simultaneously (Harrison and Pearce 2000). As elaborated below, the current research is constructed to address these recommendations.

Finally, it is important to note that within the LUCC literature, the study of the proliferation of built environments is relatively rare and when it does appear it is primarily with regard to methodologies for quantification (e.g., Mundia and Aniya 2005; Orenstein et al. 2010; Pu et al. 2008; Stefanov et al. 2001; Ward et al. 2000; Zhang et al. 2002; but also see Foresman et al. 1997 and Hunter et al. 2003 for broader LUCC analyses that include urban areas). This may be a function of its relatively small contribution to LUCC overall, as built areas are less than 2% of the earth’s land cover. Yet, at the local scale urban land encroaches upon and fragments open space, making its effective cover much larger. Conversion of open space to built space is a predominant LUCC type in specific areas, including the Netherlands (Koomen et al. 2008; Van Rij et al. 2008), Israel (Levin et al. 2007; Orenstein et al. 2010; Tal 2008) and the east coast of the United States (Foresman et al. 1997; Irwin and Bockstael 2008; Schneider and Pontius 2001).

The research presented here re-emphasizes the role of population growth on rates of land conversion from open to built space. We examine the strength of the correlation between population growth and rise in built space at three spatial scales, while focusing on the four P–E research challenges addressed above. Our specific research questions are: What is the direction and magnitude of the correlation between population growth and conversion of open to built space in Israel? How does scale of analysis affect the strength and magnitude of this correlation? Further, which policy variables influence the relationship between population growth and the amount of land converted to built space and in what ways?

Data

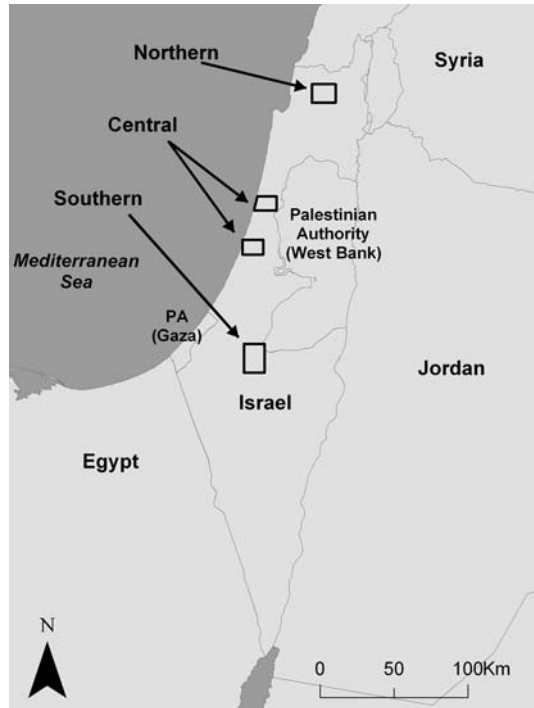
Spatial data

Our three analytical scales are defined by political boundaries: national borders, district boundaries, and locality boundaries. National scale includes all of Israel (not including the West Bank and Gaza). District scale includes the six administrative districts designated by the Israel Central Bureau of Statistics (CBS) which together comprise all of Israel. Three of these districts are Israel's major metropolitan areas (Jerusalem, Tel Aviv, and Haifa) and the remaining three (north, center, and south) include the overwhelming majority of Israel's land area. Localities comprise the smallest unit of governance, including cities, towns, and regional councils.⁴

For the locality scale analysis, we selected four study sites that included a sample of 40 localities (of approximately 250 total), which together occupy a total of 640 km² or approximately 3% of the country's land area. These sites were selected for several reasons. First, considered together they capture the human demographic gradient in Israel, from the densely populated core region to the more sparsely populated periphery. Second, they capture the ecological gradient across Israel, from the semi-arid south to the Mediterranean coast and hilly regions of the north. Third, each individual study site includes a diversity of community types (cities, towns, agricultural villages and exurban neighborhoods, Jewish and Arab communities, relatively old towns, and newly established population centers), and a variety of land-use types (settlement, agriculture, open space). Finally, for each region, we were able to obtain 1:50,000 scale maps covering a 34-year period from which we could estimate changes in the amount of built space.

The sites include 184 km² in the hilly northern Galilee region around the city of Carmiel ("Carmiel"); 133 km² between Ra'anana and Netanya, north of Tel Aviv ("Sharon"); 135 km² around Rishon L'Tzion south of Tel Aviv ("Rishon"); and

⁴ Locality boundary data are updated up to 2002. Locality boundaries have been modified in the past, including the creation of new local authorities and the transfer of undeveloped land between local authorities. In 1961, there were 179 local councils nationwide, compared to 194 in 1972, 222 in 1983, and 251 in 1995. There was also a sharp increase in the number of communities, rising from 873 in 1961 to 1,178 in 1995 (MoI 2000). Recently, the trend in establishing new local councils may be reversed as pressure grows from the national government to merge municipal councils into larger administrative units (MoI 2003).

Fig. 1 Study sites in Israel

270 km² in the semi-arid southern region around the city of Beer Sheva (Fig. 1). We taxonomize the 40 localities situated within the four research sites by region (north, center, and south), ethnicity (Jewish or Arab), and community type (rural or urban) and analyze the amount of land conversion from open to built space as a function of these variables. We include both municipalities and local councils under a single characteristic category of “urban” and treat each regional council as a single analytical unit. The justification for this taxonomy is that each of the variables can serve as a proxy for policy priorities, e.g., spatial redistribution of population or encouraging or discouraging spatial growth of certain community types.

Estimating built space

For estimates of developed land at the national and district level, we use data provided by Mazor (1993).

For quantification of developed land at the local scale, we generated a data set using 1:50,000 maps produced by the Survey of Israel. These maps (Fig. 2, top), updated at every 3–7-year intervals, include structures (buildings, roads, infrastructure), as well as topography and land use (agriculture, forests).⁵ We scanned and

⁵ We note that the maps updates did not always correspond to census years from which we take our population data. In order to address this discrepancy, we used all of the maps published prior to a given census year to quantify developed area prior to that year, thus synchronizing the time periods for the population and spatial data as best as possible.

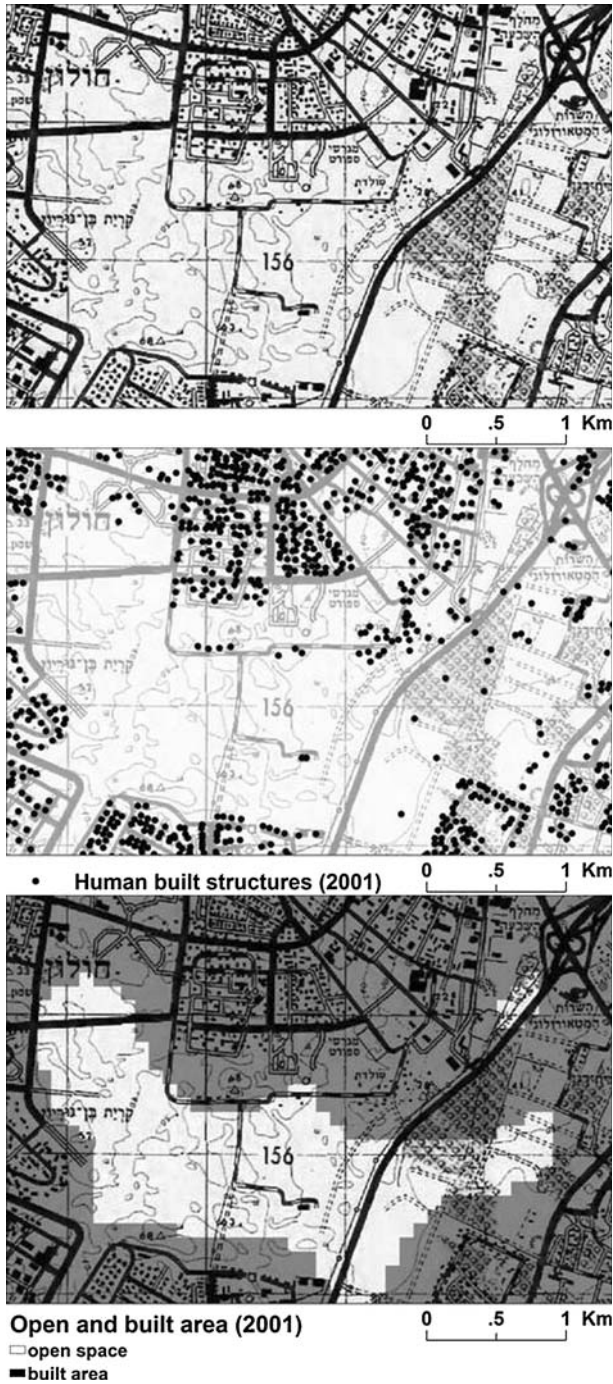


Fig. 2 Process for generating estimates of developed area over time. **a** sample portion of study site, **b** human-built structures as point data, and **c** the developed area grid

geo-referenced the maps and screen-digitized all human-built structures as map objects (Fig. 2, middle) that were assigned the following attributes:

- (1) X and Y coordinate with one meter precision;
- (2) year of appearance on a map;
- (3) year of disappearance, if any (there were two such occasions in which structures appeared on earlier maps and later disappeared: immigrant camps built in the 1950s and again in the 1990s to facilitate Jewish immigration, and structures that were cleared for road building or new structures);
- (4) geographic location (center-core, northern periphery, southern periphery)
- (5) name of community (town, city, etc.) in which each structure was located.

Digitizing objects from the “dumb raster” background of the scanned survey maps provides the important advantage of enabling computation of human-built structure density grids using standard GIS applications. We estimated the point density of human-built structures, expressed as number of structures/km². We assigned to each 100 × 100 m grid cell the value equivalent to the number of structures occurring within a 500-m radius of the cell, applying a kernel-based smoothing function. Structure density values ranged from 0 to ~1000 structures/km² (Fig. 2, bottom).

We defined open space in our density grid maps as any 10,000 m² (one hectare) pixel with fewer than 20 structures/km². By means of this threshold, we allowed areas that may have had some individual structures (ruins, pumping stations, agricultural sheds) to be defined as “open space.” We do not suggest that these areas are completely undeveloped. Indeed, open space in the “Rishon” study site includes an airport, a sewage treatment plant, a landfill, and several military installations whose structures do not appear on these maps. Furthermore, we have not included roads in our definition of developed area. Had we classified roads and areas in close proximity to roads as developed, our estimates for developed land would have been significantly higher. On the other hand, because our estimates of developed area are based on proximity to a specified number of structures, pixels are classified as developed if they are either built or in close proximity to built areas.

We observed that the choice in thresholds has a significant effect on approximations of open space, especially in regions where the settlement pattern is more dispersed (e.g., regional councils). Lowering the threshold lowered the amount of open space among dispersed settlements, while it had a minor impact in areas with high-density development. Key factor is that the methodology for estimates of open space is consistent across study sites and over time.

Comparing 1:50,000 survey maps to a high-resolution aerial photo, we observed that the maps do not include every built structure, particularly in densely developed areas. However, the extent of developed area proved to be consistent with the aerial photos. We compared the survey map to the aerial photo in 15 randomly selected areas with varying structure densities and defined a linear relationship between the map counts of structures and the actual counts derived from the aerial photo. The survey maps generally include one-quarter of the actual number of structures in high-density built areas, with higher accuracy in less densely built areas. While this

affects structure density, it had a negligible effect on the spatial extent of our estimates of developed area.

By means of the high resolution aerial photograph, we conducted an accuracy assessment of the built area maps for three of the four research sites. Overall accuracy (correctly defined pixels) varied between 79 and 92%. Commission errors (pixels defined as built that were actually open) varied between 17 and 27%, and omission errors (pixels defined as open that were actually built) varied between 29 and 40%. Data registration errors account for 25–50% of the errors, and these errors contributed roughly equally to both error types. Therefore, registration errors did not affect the net accuracy of our built area maps. For a full assessment of this methodology compared to the use of satellite imagery, see Orenstein et al. (2010).

We also estimated the proportion of land suitable for agriculture in each local authority. We derived these data from several sources. For the two study sites in the central region of the country (“Sharon” and “Rishon”), we used GIS layers of agricultural suitability produced for the Israeli Interior Ministry Planning Office (Gonen 2000). This survey assigned agricultural suitability according to soil type and depth, slope, and the presence or absence of cultivated agriculture at the time of the survey. However, the map also included developed land. Because this map was created in the late 1990s, we had to assess the agricultural suitability of land that had been built upon during the period covered by our research. In order to determine the suitability of these lands, we identified the land that had been built on between 1961 and 1995 and then defined agricultural suitability for these areas according to (1) soil type based on ca. 1960s mapping (Soil Conservation Service 1966), (2) proximity of land currently defined as agriculturally suitable, and (3) topography (slope less than 6°, adopting the convention from Gonen 2000). For the northern and southern sites, which were not identified in the 1960s mapping, we defined agricultural land according to soil type (Dan et al. 1976; Soil Conservation Service 1966) and slope derived from a digital elevation model.

These efforts resulted in data defining built and open space for the national, district, and local scales, with an additional variable of “open space suitable for agriculture” for the smallest (local) scale of resolution.

Population data

Population data for all the three scales of analysis are available from censuses conducted in 1961, 1972, 1983, and 1995 (CBS 1997). For the locality scale analysis, the census provides population numbers for each Israeli city, town, and village, as well as defining the dominant ethnicity (Jewish, Arab Muslim, and Christian, Bedouin, and Druze) and community type (e.g., moshav, community settlement, urban locality, etc.). We determine the population of regional councils by summing the populations of the individual communities within each regional council. For cities and local councils that were only partially within one of our research sites, we computed the proportion of built area of the locality that occurred within the study site, and, assuming uniform spatial distribution of population within the localities, adjusted the population size within the study site accordingly.

Table 1 Aggregations of the spatial data and summary statistics for three different divisions of 40 local authorities

	Number of local authorities	Total area (km ²)	Total area suitable for agriculture (km ²)	Total population (1995)
Region				
North	14	160	25	100,000
Center	19	250	200	630,000
South	7	230	53	180,000
Ethnicity				
Arab	15	87	30	96,000
Jewish	25	550	240	810,000
Urban/rural				
Urban	32	300	130	870,000
Rural	8	340	140	33,000

Note that population estimates are adjusted downward to account for local councils and municipalities that do not fall entirely within the study site. Inconsistencies between the aggregations are due to rounding errors. The total area suitable for agriculture includes land that is both open and built upon

While the national and district scale analyses included the entire population, the locality scale included a sample of the approximately 250 localities in Israel. The 40 localities within the four study sites had a combined 1995 population of 910,000 people, or 16% of the country's population. The 1995 population distribution among our four study sites is 11% north, 69% center (two sites), and 20% south, as compared to the overall population distribution of 23% north (Haifa and Northern District), 60% center (Tel Aviv, Jerusalem, and Central Districts), 14% south (Southern District). The spatial and demographic statistics for the communities in the four study sites are seen in Table 1. We have under-sampled the north by choosing an area away from metropolitan Haifa, and over-sampled the south by including Beer Sheva and its environs. Assuming homogeneous ethnic composition within local authorities, our 1995 population sample is 10% Arab and 90% Jewish. The 1995 census indicates a national ethnic composition closer to 20–80%, so we have under-sampled Arab populations. Finally, only 4% of our population sample resides in regional councils (“rural”), while the national figure is 9%; as such, we have over-sampled high-density urban areas. These errors would not affect our assessment of what is happening within the localities themselves, but they do have implications for our ability to scale up the results of the local analysis to the national level.

Methods—linking population and land development

Bivariate analyses

Our first analysis of the relationship between population growth and the amount of built land was a visual analysis of the graphed data at all three spatial scales and a

simple bivariate analysis at the national and district scale. We consider these variables at the national level both with and without the Beer Sheva sub-district because this sub-district includes more than half of Israel's land, but less than 10% of its population. The graphed data for the national and district scale displayed an exponential relationship, and so we use a power regression to assess the strength of the correlation between population growth and the amount of built space. This indeed provided a better fit for the data than a simple linear regression. For the locality scale, we use a more complex regression model described below.

A sprawl indicator

As a second approach to examining population growth as related to land development, we use a variation of the commonly used sprawl quotient, which compares the growth rate of built-up areas and the population growth rate within a given spatial unit. (Frenkel and Ashkenazi 2008). Sprawl, in this case, is considered to be development of land at a rate faster than the population growth rate, thereby leading to lower population density within built areas. Our indicator calculates the number of hectares of land developed per additional 1000 people added to the population during a given time period (Eq. 1). The higher the indicator value, the more land extensive the pattern of development or the more sprawl it represents within the spatial unit.

$$S = (LD_0 - LD_1)/(P_0 - P_1) * 1000 \quad (1)$$

where S , Sprawl indicator; LD_0 , LD_1 , Land developed (ha) at time 0 and 1; P_0 , P_1 , population at time 0 and 1

A multivariate regression model (locality scale)

In order to discern possible intervening variables associated with amount of land development at the local level, we constructed a main-effects, multivariate linear regression model for the locality scale data. Our dependent variable is the area of land (ha) developed within each locality between two census periods (years; 1961–1972, 1972–1983, 1983–1995) and between the entire time span under consideration (1961–1995). Our independent variables include population growth (change in population size between t_0 and t_1 ; x_1),⁶ the number of hectares of open space at t_0 (x_2), and the number of hectares of open agricultural land at t_0 (x_3). These variables are used to test the strength of correlation between the amount of land developed and (a) population growth, (b) land availability for development at the beginning of the period, and (c) agricultural land availability. Our primary assumption was that there will be a strong, positive correlation between the amount of land developed and population growth, even with the various control variables representing land availability (open and agricultural land).

⁶ We used local population data to develop several additional variables: population at t_0 , population density at t_0 (population divided by the total area built in the locality), and population growth during the interim period. Owing to strong covariance among these variables, only population growth was used in our statistical analysis.

Table 2 Analyses for investigating the linkage between population growth and land development for each spatial scale

Scale	Analyses
National	Bivariate; sprawl indicator
Regional (6 districts)	Bivariate; sprawl indicator
Local (40 localities)	Multivariate; sprawl indicator

In addition, we used three dummy variables as controls that describe the socio-economic and ethnic characteristics of the local authority, including urban/rural (x_5), Arab/Jewish (x_6), and periphery/core (x_7). There are compelling reasons to believe that these three characteristics may mediate the relationship between population growth and land development, as each characteristic carries land-use and demographic policy implications. Recall, as reviewed previously, scholars have placed a high importance on understanding the policy context in which the P–E relationship is being studied. Here, each of the aforementioned variables serves as a proxy for broad policy objectives: the bias toward rural development in agricultural settlements, the preference for encouraging Jewish spatial control and, related to both, the effort to redistribute the Jewish population from the demographic core region to the peripheries in the north and south of the country, respectively.⁷

Our final model applied at the locality scale is

$$y = \alpha + \beta_0 x_1 + \beta_1 x_2 + \beta_2 x_3 + \beta_3 x_4 + \beta_4 x_5 + \beta_5 x_6 + e \quad (2)$$

where Y , land developed in locality between t_0 and t_1 (ha); x_1 , population change between t_0 and t_1 (#); x_2 , open space at t_0 (ha); x_3 , open agricultural land at t_0 (ha); x_4 , urban/rural character (dummy; urban = 1); x_5 , Arab/Jewish character (dummy; Arab = 1); and x_6 , periphery/core location (dummy; periphery = 1)

We also explore policy shifts through time by means of analyzing our results for temporal differences in the ways in which these variables mediate the association between population growth and land development. In order to do this, we run the model for each inter-census period as well as for the entire period. The comparative analyses used for each spatial scale are summarized in Table 2.

Results

Bivariate analyses

As expected, there is a positive association between population growth and land development in Israel at the national scale, and this association is slightly stronger

⁷ Based on a regression model that included percentage of open space in each locality at t_0 as an additional variable, we determined that development rates in most cases did not show any change based on the proportion of available land, even in localities where there was only a small percentage of land still available for development. Our assumption that the rate of development within a locality could be characterized as a logistic curve (as land became more locally scarce and a higher premium was placed on remaining open space, development would slow) was not supported by the data. Population density at t_0 and population size at t_0 were excluded from the model because they showed high covariance with population growth.

when the Beer Sheva sub-district is omitted from consideration (this sub-district includes more than half of Israel's land area, but is sparsely populated. Figure 3; Table 3); In other words, the rate of land development outpaces population growth. There is a negative, exponential relationship between population growth and the loss of open space. Inclusion or exclusion of the Negev in these analyses can lead to disparate results, due to the relatively large amount of undeveloped open space in the Negev coupled with the trend of concentration of development in the central and northern portions of the country. The strength of the correlation between population growth and land development is much stronger if the Negev is not considered.

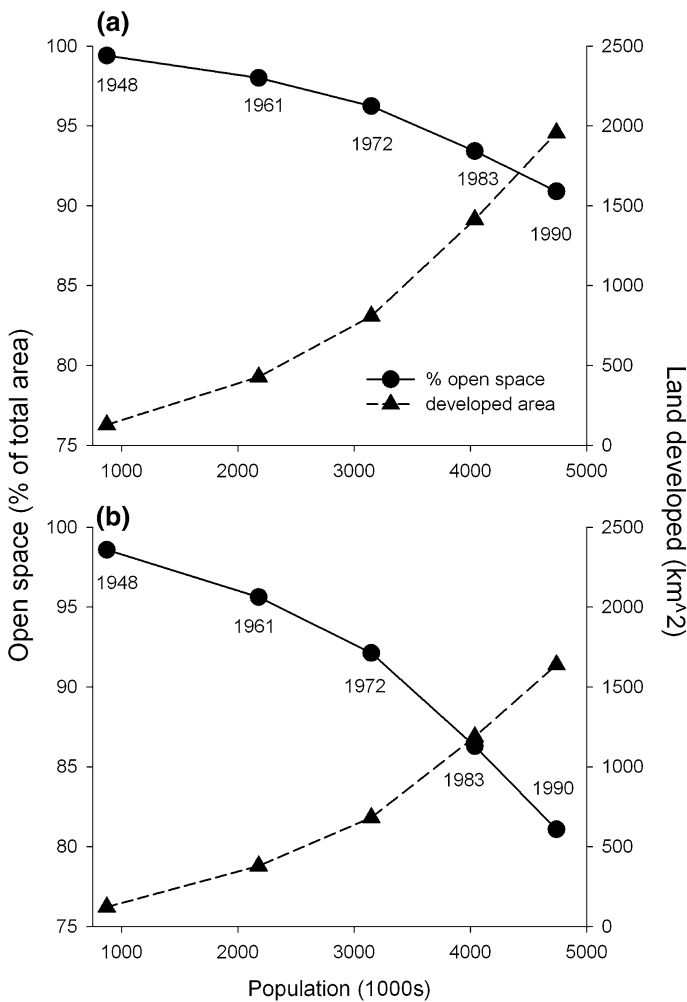


Fig. 3 Open space (% of total land) and total amount of developed land (km²) for Israel compared to population size, 1948–1990—national data with (a) and without (b) the Beer Sheva sub-district. Adapted from Mazor (1993)

Table 3 Coefficients and R^2 values for regressions using land developed (ha) as the dependent variable and population size (in 1000s) as the independent variable for national and district-level spatial scales

Scale	Region	Equation	R^2
National	Entire country	$Y = 0.0024x^{1.6}$	0.99
	Without Beer Sheva Sub-district	$Y = 0.0027x^{1.6}$	0.98
District	North	$Y = 0.0256x^{1.5}$	0.99
	Haifa	$Y = 0.0074x^{1.6}$	0.98
	Center	$Y = 0.0285x^{1.4}$	0.99
	Tel Aviv	$Y = 0.002x^{1.6}$	0.96
	Jerusalem	$Y = 0.0122x^{1.4}$	0.99
	South	$Y = 0.1585x^{1.2}$	0.99

At the district level, there is also a strong positive correlation in each of the six districts between population growth and amount of land developed (Fig. 4). In the spatially large, non-urban districts (Fig. 4a), the amount of land developed rises quickly with relatively small population additions, particularly in the north and south districts, while in the Jerusalem and Tel Aviv districts (Fig. 4b), land development amount is less sensitive to population growth. Nonetheless, the power regression analysis (Table 3) shows a strong, exponential relationship between population growth and land development amounts in all six districts.

Regardless of how the local authorities are grouped (urban/rural, Arab/Jewish, periphery/core), the amount of growth in developed land is positively correlated with population growth, with the steepest increases of built space relative to population increase occurring in the rural and the northern local authorities (Fig. 5a,c, respectively). Thus, there was a negative relationship between the amount of open space and population growth (Fig. 6). In the urban local authorities, total amount of open space fell below 50% by 1995. In the local authorities in the center of the country, the amount of open space had already fallen below 50% of the total area by 1972 and to 40% by 1995. Relative to population growth, amount of open space is falling most rapidly in the Arab, the rural, and the peripheral (north and south) local authorities. Each group (Arab, rural, and peripheral) has less dense development than the contrasting groups (urban, Jewish and center, respectively).

Examining each locality individually, we found that one of the most significant changes with regard to open/built space is the creation of a new locality in the midst of a previously existing local authority. This often explains the sudden jump from no developed land to nearly 100% developed in a single time interval for some local authorities, e.g., industrial council of Migdal Tefen in the northern site established in 1991 and Lehavim, Laqia, and Rahat in the southern site. Developing large and undeveloped portions of regional councils as local or industrial councils has significant impact on development rates.

Sprawl indicator

Sprawl at the national scale has increased as indicated by the pattern of more development per unit of additional population (Fig. 7), though this pattern is less

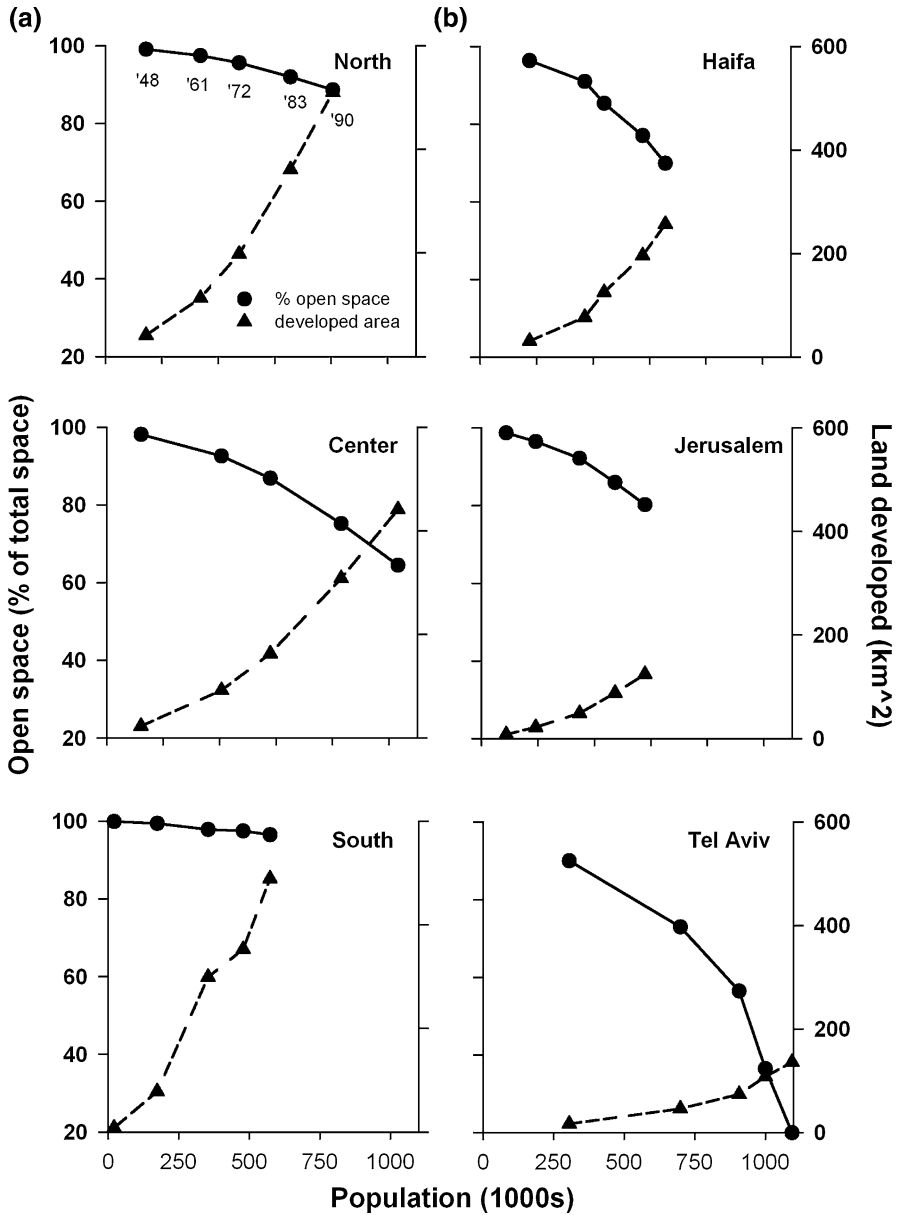
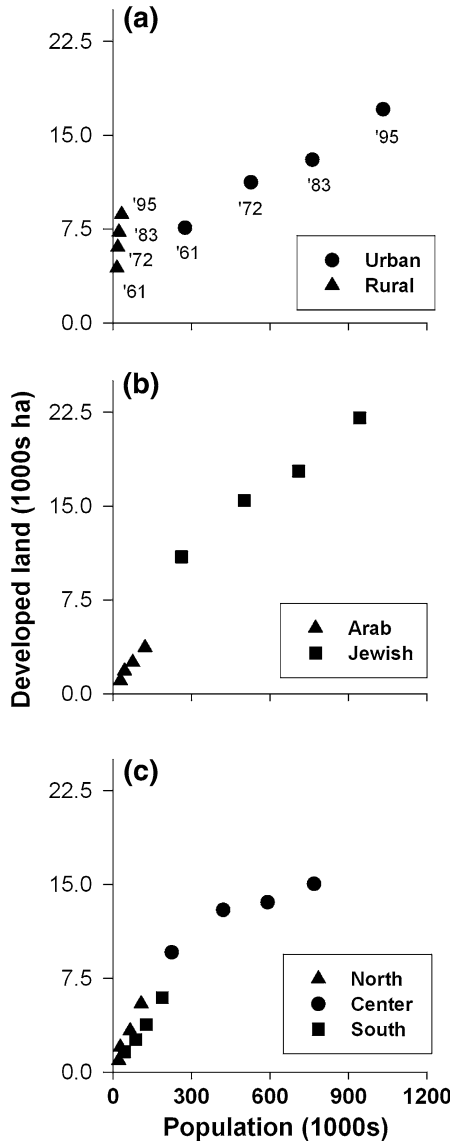


Fig. 4 Open space (% of total land) and total amount of developed land (km²) in districts compared to population size, 1948–1990—regional data according to district. Adapted from Mazor (1993). Note that the total area of the districts varies between 170 km² (Tel Aviv) to 14,000 km² (Southern district). Column a includes the larger, more sparsely populated districts and column b includes the smaller, urban districts

consistent at the district level (Fig. 8). In all the districts, sprawl is increasing over time, though development trends in the southern and Haifa districts alternate between rising periods (e.g., more sprawl) and falling periods (e.g., less sprawl).

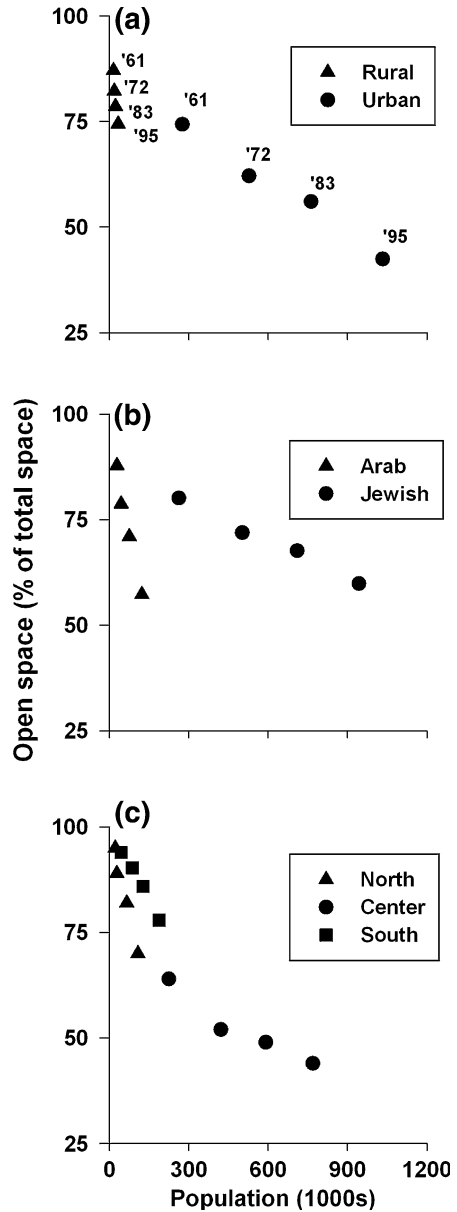
Fig. 5 Population and developed land in Israel, 1961–1995—data drawn from local authorities. Local authorities are aggregated in three different ways: urban and rural (a), Arab and Jewish (b) and geographically (i.e., north, center and south (c))



Sprawl in the southern district is consistently higher than the other rural districts, with the exception of the period of 1972–1983. Sprawl in Haifa is consistently higher than the other two urban districts. Development in the Tel Aviv district is continuously the most dense (e.g., least sprawled) of all districts, although it too becomes less dense with each consecutive period from 1948–1961 to 1972–1983, though in the last period, 1983–1990 sprawl decreases somewhat.

In Fig. 9, the sprawl indicators for the local authorities are displayed according to aggregations of urban/rural (a), Arab/Jewish (b), and north/center/south (c)

Fig. 6 Population and open space (% of total land) in local authorities, 1961–1995. Local authorities are aggregated in three different ways: urban and rural (a), Arab and Jewish (b) and geographically (i.e., north, center and south (c)). Aggregations as in Fig. 5; urban and rural (a), Arab and Jewish (b) and north/center/south (c)



characteristics of the localities, and are inconsistent with results measured at the national and district levels. We observed that over time, development becomes more dense in the rural local authorities (530 ha developed per additional 1000 persons in 1961–1972 as compared to 140 ha in 1983–1995), although it continues to be an order of magnitude more sprawled than in the urban local authorities (average 15 ha developed per additional 1000 persons for 1961–1995 with little fluctuation among

Fig. 7 National “sprawl indicator”—the amount of land developed per additional 1000 persons added to the population during the given periods. Adapted from Mazor (1993)

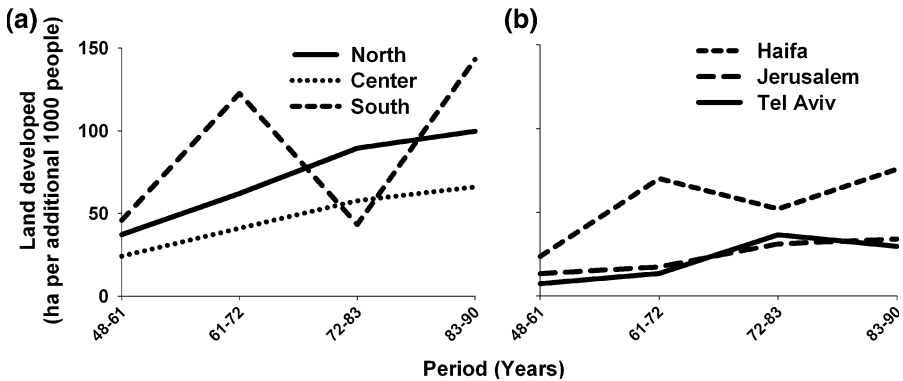
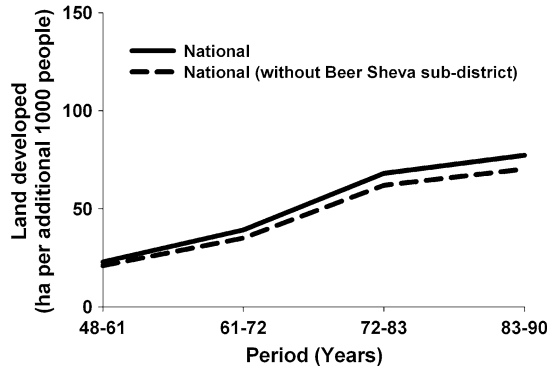


Fig. 8 District “sprawl indicator”—the amount of land developed per additional 1000 persons added to the population during the given periods for six districts (north, south, and center (a), Haifa, Jerusalem, and Tel Aviv (b)). Adapted from Mazor (1993) and CBS (2009)

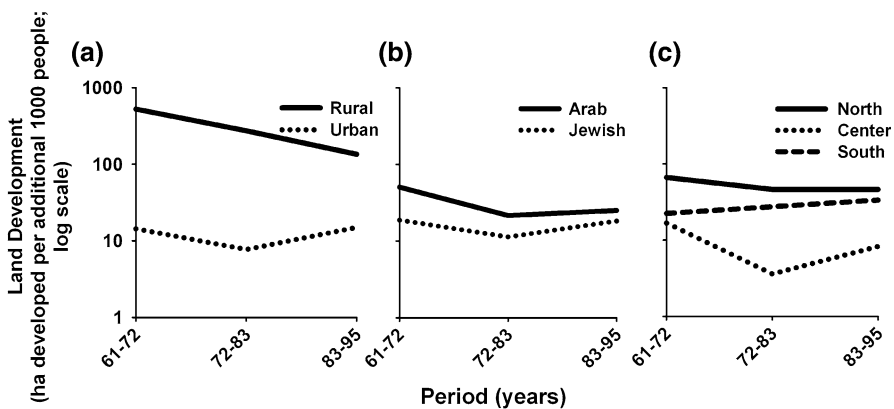


Fig. 9 Local “sprawl indicator”—the amount of land developed per additional 1000 persons added to the population during the given periods for seven aggregations of local authorities, urban and rural (a), Arab and Jewish (b), and north, center and south (c). Spatial data by authors, demographic data from CBS (1997)

decades). The sprawl indicator declines slightly in the urban local authorities between period 1 (1961–1972) and period 2 (1972–1983), and rises between period 2 and period 3 (1983–1995).

Historically, the Arab local authorities had a higher sprawl indicator than the Jewish local authorities, although there is some convergence in the most recent time period. The Arab indicator fell from 63 ha developed per additional 1000 persons in the 1961–1972 period, to 34 ha developed per additional 1000 persons in the 1983–1995 period. During the same periods, the Jewish local authorities' indicator remained mostly unchanged at approximately 19 ha per additional 1000 persons. According to the sprawl indicator, the northern local authorities have historically the most disperse development, although the indicator for the southern local authorities has risen over time.

A multivariate regression model (locality scale)

The multivariate linear regression model (Eq. 2; Table 4), which used the absolute number of hectares developed in each local authority as its dependent variable, produced statistically significant results for all the three time periods, and for the overall period. However, the independent variables with significant explanatory power varied from case to case.

For the period 1961–1972, agricultural soil availability and population growth were significantly and positively associated to the amount of land developed. For the 1972–1983 period, the amount of land developed correlated positively and significantly to the amount of open space available. Also, one of the qualitative variables was significant for this period—all other factors being equal, there were 140 more hectares developed in peripheral local authorities than center ones. These results correspond with policy decisions made during this period (see “[Discussion](#)” section). From 1983 to 1995, amount of land developed was significantly and positively correlated with population growth and, all other variables held constant, there was again significantly more development in the peripheral areas than in the core.

Finally, for the entire 1961–1995 period, we found a significant and positive association between amount of land developed and population growth, and between land developed and availability of agricultural land. Further, there was significantly less land developed in Arab local authorities and significantly more development in peripheral areas when all other factors were held constant.

Discussion

We have addressed each of the research challenges facing P–E research outlined in the introduction. With regard to direction of impact of population growth on our environmental indicator (open to built LUCC), our data show a consistent and positive correlation between population growth and increases in developed space/loss of open space regardless of spatial or temporal scale of analysis.

Table 4 Multivariate linear regression analysis for land developed (ha) in localities during inter-census period and entire period of analysis

Variable	1961–1972 [<i>n</i> = 40, Prob > <i>F</i> = 0.0000, Adj <i>R</i> ² = 0.58]		1972–1983 [<i>n</i> = 40, Prob > <i>F</i> = 0.0000, Adj <i>R</i> ² = 0.49]		1983–1995 [<i>n</i> = 40, Prob > <i>F</i> = 0.0000, Adj <i>R</i> ² = 0.76]		1961–1995 [<i>n</i> = 40, Prob > <i>F</i> = 0.0000, Adj <i>R</i> ² = 0.73]	
	β	SE	β	SE	β	SE	β	SE
Pop. growth (#)	0.005***	0.001	0.002	0.001	0.014***	0.002	0.007***	0.001
Open space <i>t</i> ₀ (ha)	0.008	0.007	0.016**	0.006	0.001	0.008	0.026	0.015
Open agricultural land space <i>t</i> ₀ (ha)	0.18***	0.036	0.064	0.033	0.092	0.047	0.32***	0.078
Urban (rural)	-81	64	-3.5	54	9.8	73	-65	140
Arab (Jewish)	-42	50	-97	39	-96	52	-230*	110
Periphery (core)	22	44	140***	34	220***	45	410***	92
Constant	29	36	-16	27	-66	34	-79	75

* *p* < 0.05; ** *p* < 0.01; *** *p* < 0.001

With regard to magnitude of the correlation, we are reminded of Palloni's recasting of the central question about P–E research: rather than asking whether population growth is a causal factor in LUCC, we ask “when and where will the effect be weak or strong” (Palloni 1994). As such, the question of magnitude is tightly linked to the remaining questions of scale and causal pathway. There is great variation in the magnitude of the relationship according to spatial scale, and analyses at multiple scales begin to reveal intermediate factors influencing population growth and the rise in built space/loss of open space that are masked at larger spatial scales of analysis.

These results show that the amount of open space falls as population size rises, but the rate of loss of open space in response to population growth varies depending on temporal and spatial scale of analysis, and according to the policy context in which the P–E dynamic is occurring. The relationship weakens at the locality scale, when the temporal scale of analysis is short, and when additional independent variables are significant. Most of these variables, including geographic, ethnic, and residential (urban or rural) context, are considered proxies for policy variables and are significantly correlated to rates of land conversion in our regression model. These findings support the consensus that spatial scale of analysis can affect the interaction between demographic variables and LUCC (Axinn and Barber 2003; Lambin et al. 2003; Mena et al. 2006; Rindfuss et al. 2004; Walsh et al. 1999).

Sprawl (more space consumed per additional unit of population) is increasing over time at both the national and district scale, yet the locality data do not corroborate these results. The locality data suggest a growing homogenization of development across the Israeli landscape. Rural development is intensifying (e.g., less sprawl), while urban development has stayed relatively consistent with regard to density. Likewise, development in Arab localities is becoming more intensive (that is, more densely concentrated), while Jewish development (which includes highly dichotomized densities from rural and urban localities) is consistent over time. The picture that emerges from locality analyses is a convergence across locality types toward approximately 20 ha of land development per additional 1000 people (although development in rural localities remains an order of magnitude higher than development in all other aggregations). This trend in homogenization corroborates previous research on development densities in Israel (Shoshany and Goldshleger 2002).

Our estimates of open-space availability in localities are consistently lower than the district level estimates. This difference (and the difference in sprawl trends noted in the previous paragraph) may be due to several reasons. First, there has been an increase in movement of population from cities toward lower density communities (suburbs and exurbs), which was particularly pronounced in the 1980s and 1990s (Frenkel, “unpublished manuscript”). This may explain why, at the local scale, levels of sprawl are constant in each community type, but at the aggregate district and national scale, sprawl seems to be rising; the proportional amounts of development are greater in lower density communities. Second, our local analysis consists of four relatively built-up regions relative to the districts in which they are embedded, and the local level study sites did not include areas devoid of settlement. This discrepancy once again underscores the importance of

analyses at multiple spatial scales. Third, the differences may be explained due to the fact that the national and district level data are drawn from a different source.⁸ This latter explanation serves as a precautionary note regarding the limitations of comparative work based on comparing different data sources.

The strength of the correlation between population growth and open-to-built space and its consistency with regard to directionality across spatial scales and time suggest a causal role of population growth, and yet its role cannot be understood without also considering multiple intervening variables. Policy and central planning play a significant role in development in Israel, and our data suggest that they serve a crucial intervening role between population growth and land development. In particular, national policies that encourage, directly or indirectly, low-density settlement patterns may have had a more significant effect on the loss of open space in Israel than the absolute increase in population size. This may explain why, on the one hand, availability of open space at t_0 did not significantly correlate with the amount of new built space (which we had considered to be an intuitive relationship) and yet, on the other hand, development in peripheries and in rural localities (where open space was most abundant) was more sensitive to population growth. Either policies guiding development may account for this, or unmeasured variables such as land value and housing costs, may be influencing the P–E relationship.

Owing to the emphasis on farmland protection that permeated land-use policy in Israel throughout its history (Alterman 1997; Feitelson 1999), we expected that proximity to agricultural land would restrain local development. Contrary to this hypothesis, between 1961 and 1972, most development occurred where populations grew the most and where agricultural land was available. There are three possible explanations: First, agricultural suitability, determined by slope and soil type, similarly defines suitability for development. Second, development from 1961—both Jewish and Arab—tended to be on agricultural land and surrounded by agricultural land; subsequent development tended to be contiguous to existing development. Finally, the greatest amount of agricultural land is found in the core region of the country, where the majority of the population lives and where there is highest demand for residential development.

The amount of land developed in the peripheral areas was significantly higher than in the core area, once variation due to population growth and other related factors are removed. Likewise, development in Arab localities was less than in Jewish localities (controlling for other factors), although this difference was statistically significant only for the full 1961–1995 study period. These results reflect a consistent Israeli policy to encourage internal migration of Jewish citizens to the peripheral areas, while concurrently restraining the growth of Arab localities (Falah 1991; Khamaisi 1993; Yiftachel and Rumley 1991), despite the preference of most Jews to live in high-density urban communities in the geographic core area of the country (Kellerman 1993). Various national policies have attempted to attract Jews to the peripheral areas (Kellerman 1993; Newman 1984, 1989). Among them

⁸ The data from Mazor (1993), while being the only data that provide estimates of built space prior to the 1990s, were received by the public and other professionals with some degree of controversy regarding its accuracy, specifically as to whether it overestimated the amount of land that had been developed in the past.

was the development of small, exurban communities with larger homes. By attracting people to these communities, policy magnifies the impact of local population growth on open space in Jewish, rural localities where the amount of land developed per capita is an order of magnitude higher than in any other type of development.

Several potentially important independent variables are not included in our model, which should be considered for future inclusion: (1) household-level demographic changes, including family size and age structure, have been shown to be important factors in explaining energy use (O'Neill and Chen 2002) and threats to biodiversity conservation (Liu et al. 2003); data in Israel show simultaneous trends of increasing residential space per capita and smaller average household sizes); (2) there is theoretical and empirical evidence that land-use change may respond directly to changes in transportation infrastructure (Heilig 1994; Muller 1995), but this remains a subject of some debate with regard to pattern and the extent of the influence (Giuliano 1995); (3) economic growth and market changes may influence the rate of land development, for instance, when greater income affords a broader range of residential alternatives or when changes in global agricultural demand decreases the value of agricultural land; and (4) land-use policies that are not related to population redistribution, e.g., policies to rezone farmland for construction.

The role of population growth has been increasingly de-emphasized in the LUCC literature, and it is thought to be of relatively low importance among possible drivers. In their comprehensive meta-analysis of 152 sub-national studies on the drivers of tropical deforestations. Geist and Lambin (2002) found population growth to be a non-significant factor, even as an underlying social cause. Its importance is also considered less than the other factors when considering desertification (Geist and Lambin 2004). Fox and Vogler (2005) find instances where population both was, and was not, correlated to forest and agricultural land-use change in southeast Asia and they projected that policies and market pressures were more likely to be driving observed LUCC.

On the other hand, Pan et al. (2007) find strong correlations between population growth and deforestation in the Ecuadorian Amazon and conclude that their findings “are especially important as they are among the first to definitively link forest cover change to population change at the farm plot level in a frontier region, in fully specified multivariate models that also control for spatial factors.”

Our results lead us to suggest that population growth continues to be an important factor impacting environmental change, despite the importance of the intervening factors presented in the research. Population growth is positively correlated with land development across all spatial and temporal scales. Intervening variables affect the strength of the relationship, but not the direction. One somewhat surprising result of the population–development relationship is that for districts in which open land is becoming increasingly scarce, an expected slowing of land development relative to population growth with a concomitant increased importance of open space was not evident. We would have expected to see the rate of land development slow as open space became increasingly rare. Rather, we see the rate of loss of open-space increase (and the rate of land

development increase) as open land reserves become smaller. This is true even in the case of the Tel Aviv district, where only a small amount of land ($\sim 20\%$) remained open space by 1990 (Fig. 4b).

Based on the research presented here, we suggest three specific ways in which population growth may significantly affect land development rates in Israel. First, the rising demand for single-family, ground-attached homes (Alterman 1997; Applebaum et al. 1989) coupled with a growing population places heavy demands for open space and pressure to rezone land. Government control of development may be influenced by economic and demographic pressures (Werczberger and Borukhov 1999). We found instances of land development that can be attributed to the combination of smaller households with a desire for larger dwellings, which may lead to land development in the absence of population growth at the locality level. This indicates that other demographic processes, in particular household size, may also contribute to land development rates, as has been shown for changes in energy consumption. Second, the political–demographic dimension of the Jewish–Arab conflict in Israel continues to precipitate population redistribution policies for peripheral areas where government sovereignty and Jewish demographic dominance are perceived to be threatened (Evans 2006; Newman 1989; Orenstein and Hamburg 2009; Yiftachel 1999). These spatial development policies encourage internal migration of Jews to peripheral regions within Israel, and since low-density development characterizes residential preferences in these regions, population growth here leads to the most significant rise in built space. Third, the possibility of wide-scale evacuation of Israeli citizens living in the West Bank may precipitate a pulse of development, not unlike past immigration waves. In the 1990s, the large scale influx of immigrants from the former Soviet Union, which increased the national population by 12% within 3 years, precipitated reconsideration of some of Israel's classic land-use positions, including the importance of protecting agricultural land (Alterman 2002). The evacuation of fewer than 2,000 Jewish settlers from Gaza in 2005 led to re-zoning open spaces along the Israel's southern Mediterranean coast and in the northern Negev (Azoulai 2005).

Nonetheless, the Israeli case study also validates the claim that demography and other single-driver explanations of LUCC are insufficient to explain patterns of land-use change (Lambin and Geist 2002; Mena et al. 2006; Palloni 1994). Government policy and institutional structures seem to play a significant role in intermediating between these variables, as has been suggested for P–E research in general (Pebly 1998).

Across all the study localities, the correlation between population growth and land development was positive, even in regression models that include spatial factors and proxies for policy regimes. This suggests that population growth should continue to be considered as an important underlying driver of environmental change and of LUCC. While Israel is unique with regard to its combined high levels of economic prosperity *and* high population growth, our case study has relevance for developed countries and regions (like the south and southwest regions of the USA) which must balance population growth and urban development with open-space conservation for ecosystem services and biological diversity.

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