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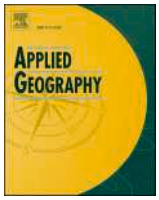

A land without people? The GIScience approach to estimating the population of Ottoman Palestine towards the end of the 19th-century

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ABSTRACT

The question of the nature and extent of population in Ottoman Palestine towards the end of the 19th century (~1880) remains one of significant implications even today. Using the PEF (Palestine Exploration Fund) maps and employing GIScience (Geographic Information Science) approaches, the mapped settlements were extracted and inspected. Based on the population estimates of the PEF surveyors in the 1870s and on the 1922 census of Palestine carried out by the British Mandate authorities, it is possible to estimate the population size in the permanent settlements appearing on the maps. It was found that 864 settlements existed within the boundaries of the PEF map. Of these, 697 settlements were within the boundaries of Ottoman Palestine, with a population of ~335,000. Most of the population was concentrated in the municipal towns while part of it inhabited rural regions in the Galilee, Samaria, and Judea. The coastal plain between Jaffa and Haifa, the Jordan Valley, and the northern Negev were considerably less populated.

1. Introduction

It was only in the 19th century that Ottoman Palestine began to attract the attention of the international community, as substantial geopolitical developments brought it into the focus of interest (Ben-Arieh, 1970; Ben-Arieh & Bartal, 1983; Ben-Bassat & Ginio, 2011; Goren, 2002). One major change was the wave of Jewish immigration to Palestine prior to the outbreak of World War I. It began in 1882 with young European Jews immigrating to Palestine following the wake of the Zionist movement (Aharonson, 1983; Ben-Artzi, 1997; Penslar, 1990). The newcomers encountered the local Arab population (Muslims and Christians) of Palestine, residing in the major cities and in villages and hamlets in the rural regions. The confrontation between the two cultures yielded almost immediately a conflict, which persists to this day. At first, it was a somewhat local conflict, lacking apparent ethnic characteristics (Aharonson, 2000); however, it gradually evolved into a dispute between the Jewish and Muslim Arabs ethnic groups, triggering a substantial ongoing, unresolved geopolitical strife, which has lasted more than a century (Arnoni, 1968; Gelvin, 2014; Ohana-Arnon, 2013). This schism resulted in several contradicting narratives constantly nourished by both sides. One narrative concerns the size of the population in Ottoman Palestine at the time shortly before the first Jewish immigration wave. The Arab narrative describes Ottoman Palestine as relatively inhabited, presenting itself as a counter-narrative to the Zionist one, and thus ignoring even the voices of the early Zionists who acknowledged the existing Muslim and Christian Arabs (Khalidi, 2010). The Jewish narrative, on the other hand, tends to understate the size of the Arab population (Muslims and Christians) at the time, relying primarily on testimonies of contemporary travelers and pilgrims (e.g., Twain, 1962). Some Jewish commentators have quoted a phrase used in 1901 by Israel Zangwill, presenting Palestine as "a country without a people" and the Jews as "a people without a country" (Zangwill, 1901). This 19th-century notion has been both erroneously attributed to Zangwill and misinterpreted as evidence that the land was indeed physically desolate (Whitelam, 2013).

A major cause for the controversy may have been the fact that the Ottoman rule did not conduct a regular and consistent census during the 19th century. Partial censuses were conducted in 1876 and 1883, but it was not until 1905 that the first complete official Ottoman census was carried out in Palestine (Pagis, 1997, pp. 9–18). Two censuses followed, by the British authorities, after World War I: the first in 1922 (Barron, 1923) and the second in 1931 (Mills, 1932). In the absence of official Ottoman data from the 19th century, scholars had to rely on other sources. One group comprises household estimates made by foreign consulates, such as those carried out by the British consul William Werry (~1839), the commercial consulate of the French Ministry of Foreign Affairs (1847), the Prussian consul Georg Rosen in Istanbul (1849), and the American consul in Beirut Jerjes Jamal, with population estimates

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varying between 239,000 and 365,000 individuals (Grossman, 2007). Another group of sources includes partial assessments made by scholars, travelers, and survey expeditions (e.g., Baedeker, 1876; Conder & Kitchener, 1881-1883; Guérin, 1868; Hartmann, 1883; E.; Robinson & Smith, 1856; Schick, 1896; Schumacher, 1887, pp. 169–191; Socin, 1879). Though these assessments are incomplete, tend to occasional exaggerations, and, at times, contradict each other (Arnon, 1977; Ben-Arieh, 1981; Nassar, 2011), they have been used by various scholars to estimate the population at the time e.g., Ben-Arieh (1986); McCarthy (1990); Abir (1975); and Grossman (2007, 2012), with total estimates of 380,000, 440,000, 145,600, and 340,000–370,000 people, respectively.

The rapid development of GIS (Geographic Information Systems) and GIScience (Geographic Information Science) during the last few decades enables the development of new approaches and creation of new functionalities facilitating the analysis of spatial data (Goodchild, 2010). The term GIS refers merely to the software and technological tools (Wright et al., 1997) while GIScience is the scientific theoretical themes and methodologies that are associated with the analysis of spatial data (Mark, 2003). As far as old cartographic material is concerned, GIScience offers a wide set of quantitative and qualitative capabilities (Cope & Elwood, 2009; Wang, 2006) that are suitable for various spatial applications (Sui, 2015). The scientific branch of GIScience for the study of historical scenarios is referred to as Historical GIS (HGIS), which stands, to date, at the forefront of historical geographical research (Gregory & Geddes, 2014). Examples may be found in various cartographic-based analyses (Bodenhamer et al., 2015; Levin, 2006; Schaffer & Levin, 2016; Zohar, 2019), 2D or 3D historical landscape reconstructions (Davie & Frumin, 2007; Georgoula et al., 2013; Nakaya et al., 2010; Rubinowicz & Czyńska, 2015; Zohar, 2017), and studies resolving complex scenarios of past phenomena (Bender et al., 2005; Katz & Crouvi, 2007; Verhagen & Jeneson, 2012; Zohar & Erickson-Gini, 2020). Lately, a review of the available cartographic material associated with late Ottoman Palestine has been made and concluded that the available corpus is insufficiently exploited, and that examining the material using GIScience and HGIS may add substantial theoretical knowledge one cannot acquire when relying solely on textual sources (Zohar, 2020).

The number and density of the residential features included in a historical map may be a proxy for the population's characteristics (DeBats & Gregory, 2011; Frantzman et al., 2014; Hedefalk et al., 2017). In this paper an innovative approach is suggested to resolve the question of the size of the population of Palestine in the second half of the 19th century. Using GIS software and GIScience methods it is now possible to extract data on residential features from a historical map and, subsequently, to characterize the population and assess its size using spatial methodologies that add to and complement the traditional population estimates. It seems that the most suited maps for this task, which describe accurately the end of the 19th-century settlements, are the Palestine Exploration Fund (PEF) maps (Conder & Kitchener, 1880) (Fig. 1). Published in 1880, following a consistent survey conducted in 1871–1877, these maps comprise an accurate and reliable corpus of spatial data, from which one can extract information for analysis (Levin, 2006; Schaffer et al., 2016; Schaffer & Levin, 2014, 2016). In this paper the PEF maps are used in conjunction with spatial GIScience methods to address the following research questions: (1) What was the permanent population towards the end of the 19th-century (~1880) in Ottoman Palestine? (2) What were the spatial patterns of the permanent settlements at the time? The term Ottoman Palestine refers to the area the PEF surveyors had named the 'Biblical land' i.e., from Bir es Seba (Bee'r Sheba) in the south to the Litany River in the north (Conder & Kitchener, 1881-1883) (Fig. 1).

2. Data and methodology

The corpus of the PEF maps contains 26 sheets at a scale of 1:63,360 (Conder & Kitchener, 1880). These cover the region from Bir es Seba (present day Be'er Sheva, Israel) in the south to Tyre (southern Lebanon)

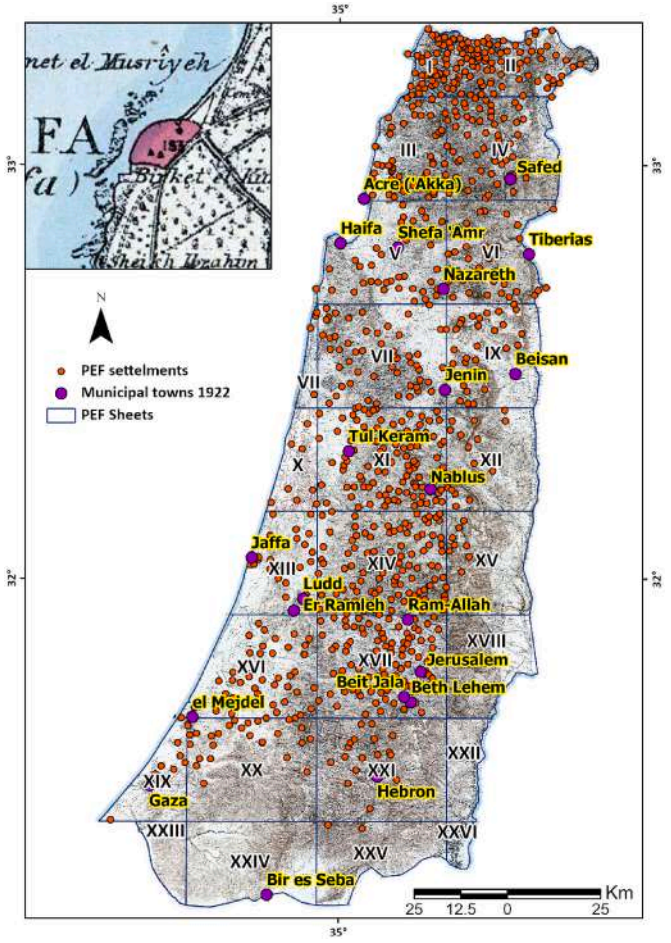

Fig. 1. The PEF maps (26 sheets) with the extracted settlements (864 settlements altogether). The municipal towns in 1922 listed by Barron (1923, Table III) are marked by purple circles. Note that at the 2nd half of the 19th century Tul Keram and Beisan were not considered as towns (Amiran & Shahar, 1960) while Bir es Seba was not populated (Conder & Kitchener, 1881-1883). Hence, the latter was excluded from the analysis. The labels of the towns accord with their 19th-century names as they appear on the PEF maps but the following towns are presently more commonly referred to by their modern-day name: Bir es Seba (Be'er Sheva), el Mejdel (Ashkelon), er Ramleh (Ramleh), Ludd (Lod), Ram-Allah (Ramallah), Tul Keram (Tulkarm), Beisan (Beth Shean), Shefa 'Amer (Shefar'am) and Acre ('Akko). The inset map presents the delineated area of Jaffa as portrayed by the cartographers.

in the north and from the Jordan River in the east to the Mediterranean Sea in the west (Fig. 1). Consistent study of the PEF maps has begun in the 20th century and already in 1953 (Amiran, 1953) used it to examine the settlement pattern of 19th century Palestine. In 2006, all 26 sheets of the map were scanned and pieced together (Levin, 2006) using a projection to the ITM (Israel Transverse Mercator) coordinate system (Mugnier, 2000). Levin also evaluated the map registration error (RMSE = 74.4 m), which, in light of the map's scale, implies that it meets modern standards of accuracy (Minnesota-Planning, 1999; A. H.; Robinson, 2017). The complete mosaicked map was downloaded from doi.pangaea.de/10.1594/PANGAEA.819656 (last accessed April 21, 2021), curtesy of N. Levin.

All of the permanent settlements appearing on the map were digitized at a scale of <1:3000 to trace accurately the delineation of their areas and, accordingly, avoid errors (Schaffer & Levin, 2015). Altogether, 864 permanent settlements were digitized, and their area (in sq m) was calculated. It is to be stressed that tribal and nomadic groups existed at the time (Levin et al., 2010) but were excluded from the analysis. Additionally, the German Colony (located outside the borders

of Ottoman Haifa) was excluded as well for being exaggeratedly portrayed in the map, in comparison, for instance, with the city of Haifa. The details of the digitized settlements appear in three consecutive index volumes dedicated to the Galilee, Samaria, and Judea (Conder & Kitchener, 1881-1883). These volumes contain population estimates for 349 settlements (out of the 864), based on earlier by estimates by Victor Guérin (Guérin, 1868), Ernest Socin and pére Liévin de Hamme (Baedeker, 1876), and the British vice consul Edward Thomas Rogers (1859). Yet, the population estimate of many of the settlements was occasionally indecisive. In several cases, it was impossible to derive the population size from the PEF records, because the given value was the sum of the population size of two settlements. This is the case, e.g., for the village pairs of Mugar and Mansurh and of Samka and el-Hama, with a total population of 1377 and 976, respectively. In 29 other cases the PEF expedition's estimates seem to be exaggerated. In these cases, they were cross-correlated with the records of the 1922 British census (Barron, 1923) to verify the outliers; in all cases in which the size of the ~1880 population was greater than the value of the 1922 survey, the ~1880 value was adjusted to that of 1922. The PEF surveyors also provided a qualitative description of most of the settlements' sizes (Table 1). In addition to the ~1880 PEF estimates, a population size at the beginning of the British Mandate rule was noted for 614 settlements, based on the results of the post-World War I British census, carried out in 1922 (Barron, 1923).

To assess the population size in 515 settlements that had no available PEF population estimate, a statistical model was applied based on the 349 settlements that had one. The fitted model verified the association between the areas of the 349 settlements and their respective populations. Given the high accuracy of the PEF maps and the fact that the British used delineated shapes to represent the settlements' area (see, e.g., Jaffa in Fig. 1), the underlying assumption is that the area of these shapes may proxy the size of the population—that is, larger shapes represent larger populations, and smaller ones, smaller populations. Additionally, as the density of a settlement depends on its nature, one must consider that municipal towns tend to be more crowded than rural regions and therefore contain more people per area unit. Amiran and Shahar (1960) list 18 towns in Palestine during the 2nd half of the 19th century but omit Tyre (that is included in the PEF map). For 18 of these towns, a PEF population estimation exists (the exceptional town is Ram-Allah) resulting in an average population density (per dunam) of 40.6. For comparison, the adjacent average density of 226 rural villages with a PEF population estimation and more than 100 residence is 14.5. Thus, for inspecting the area/population ratio, the area of the towns was enlarged to compensate the towns their higher densities. Considering the urban/rural densities ratio, one is ought to double (at least) the area of the towns. Nevertheless, since the values used to derive these densities are mere estimations, a conservative approach was preferred and an area enlargement of only 50% was applied. For testing and fitting a prediction model between the size (the explanatory parameter) and the population (the response parameter), a normal distribution is preferred for both parameters; however, as neither parameter is normally distributed, a logarithmic transformation was applied (Fig. 2). The normal Q-Q plot (Fig. 2a) presents sets of quantiles corresponding to the transformed values of the area and population of the 349 settlements. The quantiles' points form a roughly straight line for both parameters, implying they are normally distributed. The boxplots in Fig. 2b and the density curves in Fig. 2c support the normality characteristic of both parameters, although the kurtosis of the area parameter is much higher than that of the population parameter, and both are slightly skewed to the right. For comparison, the distribution of the logarithmic transformation of the area of settlements that were not attributed with PEF population estimation is presented (Area_NP, Fig. 2). The outliers of this distribution are smaller and closer to the median value, but the interquartile range (Q1-Q3) and the density curves are not significantly different. In other words, apart from several settlements with large area, the area of the settlements was not a dominant factor of the British surveyors in making a population estimation.

Once a model was fitted, the population size was evaluated also for the remaining 515 settlements with missing PEF estimates. Then, the spatial relationships between the settlements and the populations were examined to trace and characterize the spatial patterns. There are two parameters that are crucial for such examination. The first is the grid cell that is used to summarize the included observations. Choosing the correct grid cell is important in order to avoid masking of information by using bins that are too large or giving unnecessary emphasis to outliers by using bins that are too small. Therefore, the size of the desired cell was calculated using the following formula (after Greig-Smith, 1983):

$$S = \frac{2^{*}A}{n} \quad (1)$$

whereas S is the desired grid cell, A is the area of the inspected region (i.e., the entire area of the PEF map), and n equals the number of settlements. Accordingly, given the total area of the map is 15,607 sq km and n is 864, the resulted size of the grid cell is 36.08 sq km, i.e., a desired grid cell of 6 × 6 km. This size was used to summarize spatially the statistics regarding the area and population.

The second parameter required for the spatial examinations between neighboring features is the search distance. To determine this value, the Global Moran's I index was selected. This index measures the spatial autocorrelation between features based on their location and an attribute value thus implying of the quality of correlation withing a given a search radius (Chen, 2013). In this case, the attribute value is the population that was set as the numeric input autocorrelation field. Then, the computation of the index was iterated several consecutive times, each with a different search distance (as the conceptualization of spatial relationships) starting with 1500 m and incremented by 500 m. The resulted z-scores of the iterations rise from −0.513399 (at 1500 m) to 0.015548 (at 2500 m) and then decrease to −0.100309 (at 3500 m). Thus, a search radius of 2500 m was selected for the implementation of spatial analyses such as the neighborhood summary and density-based clustering. The former summarizes the statistics of one or more numeric field using local neighborhoods around each feature, while the latter detects clusters of point features based on their spatial

Table 1
Qualitative descriptions by PEF surveyors of size and nature of the settlements.

Descriptions of small forms of settlements	Descriptions of medium-sized forms of settlements	Descriptions of large forms of settlements	Other descriptions
A village of smaller size	A village of moderate size	A good-sized village	An ancient village
A little village	A medium size village	A large and important village	A village
A small village	A middle-sized mud village	A large village	An ordinary mud village
A very small hamlet	A village of middling size	A large mud village	A semi-ruinous stone village
A small hamlet	A moderately large village of mud	A large and nourishing Christian village	
A straggling village	A moderate-sized village		
A somewhat small village	A village of medium size		
A small and partly ruinous stone village			
A few houses			

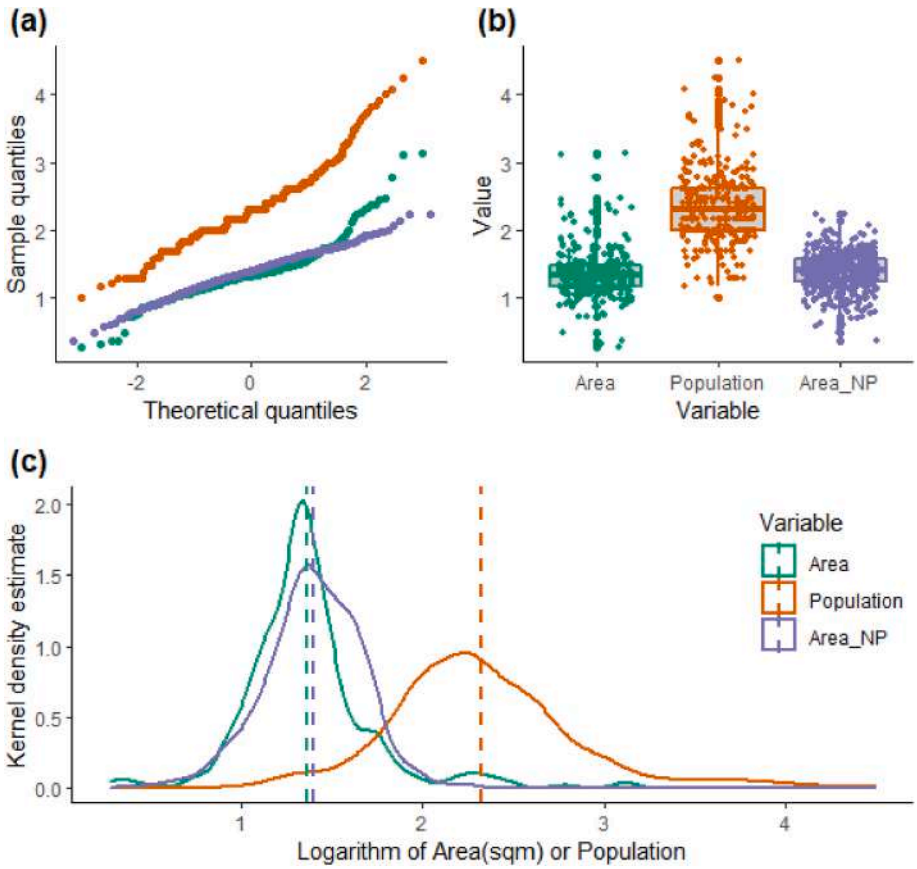

Fig. 2. The distribution of the logarithmic transformations of the area (square meters, in green) and population (in orange) of the settlements attributed with PEF population estimation (N = 349). Alongside, a similar distribution of the area (Area_NP, in purple) of the settlements without PEF estimation (N = 515): (a) normal Q-Q plot; (b) boxplots of the three distributions; (c) density curves presenting normal distributions of the three transformed parameters. Apart from exceptional outliers, the distributions of both area parameters (Area and Area_NP) are not significantly different from each other but their kurtosis is higher than the population distribution, and they are slightly skewed to the right.

distribution.[1]

The fitted statistical model between the transformed area and population was applied and tested using the R software, while spatial analyses were carried out using ESRI© ArcGIS Pro (version 2.7).

3. Results

3.1. Population prediction

A linear regression model was fitted for the 349 settlements that were attributed with population estimates by the PEF surveyors. The model verified the relation between the logarithmic transformations of the area of the settlements and their population as the response and explanatory parameters, respectively (Fig. 3 and Table 2). The fitted model can be expressed as follows:

$$\log(\text{Population}) = 0.709 + 1.19 \times \log(\text{Area}) \quad (2)$$

The coefficient of determination (R^2) of the model is 0.63 ($p < 0.0001$), whereas the intercept is 0.709, and the coefficient is 1.19 (both significant). The residuals of the model reflect the difference between the observed and predicted response values (Table 2). The minimum and maximum residuals are −1.06530 and 0.78566, respectively, while the 1st, 2nd (median), and 3rd quartiles are −0.19053, 0.003575, and 0.21377, respectively—that is, they reflect a distribution that appears to be symmetrical. Additionally, the coefficients have a low standard error with t-statistic values that are significant and are relatively far from 0, which may indicate that a relationship indeed exists. The F-statistic, which also indicates the relationship between the explanatory and the response variables, is 599.5. Thus, one can reject the null hypothesis of no relationship between the area and the population.

The visual inspection of the residuals is presented in Fig. 4. The residual vs. fitted values (Fig. 4a) and the normal Q-Q (Fig. 4b) plots demonstrate a nonlinear relationship (i.e., no evident pattern) and a normal distribution of the residuals, respectively. The scale-location plot (Fig. 4c) shows that the residuals are spread equally. The last plot (Fig. 4d) presents the residuals vs. leverage, demonstrating no influential cases that are beyond the Cook's distance lines (Cook, 1977). Altogether, these four plots reinforce the validity of the fitted model, which can be used, consequently, to estimate the population of the remaining 515 settlements, which were not attributed with population estimates by the PEF surveyors. Altogether, after assigning population values to the 515 settlements that had no PEF population estimates and combining them with the 349 settlements for which there were estimates, the total population of all settlements is estimated as 374,302, with a mean, minimum, and maximum of 432, 10, and 31,500, respectively. The combined distribution of the logarithm of the estimated PEF (349 cases, population of 216, 891) and predicted (515 cases, population of 157,411) populations is presented in Fig. 3b. Accordingly, most of the cases are concentrated around the median (216), while the density curve is skewed to the right beyond the mean value (432), due to the existence of largely populated cases such as the towns of Jerusalem (31,500) and Gaza (18,000).

[1] These are two built-in tools of the ArcGIS Pro software. The following parameters were used:(a) Input parameters used for the 'neighborhood summary statistics' tool: (1) fields of summary: "population and area"; (2) distance band: "2500 m"; (3) method: "unweighted"; and (4) focal features: "Do not include focal feature in calculations".(b) Input parameters used for the 'density-based clustering': (1) clustering method: "self-adjusting (HDBSCAN)" and (2) minimum features per cluster: "7" (the median value of the highest quantile range achieved in the 'nearest neighbor' analysis).

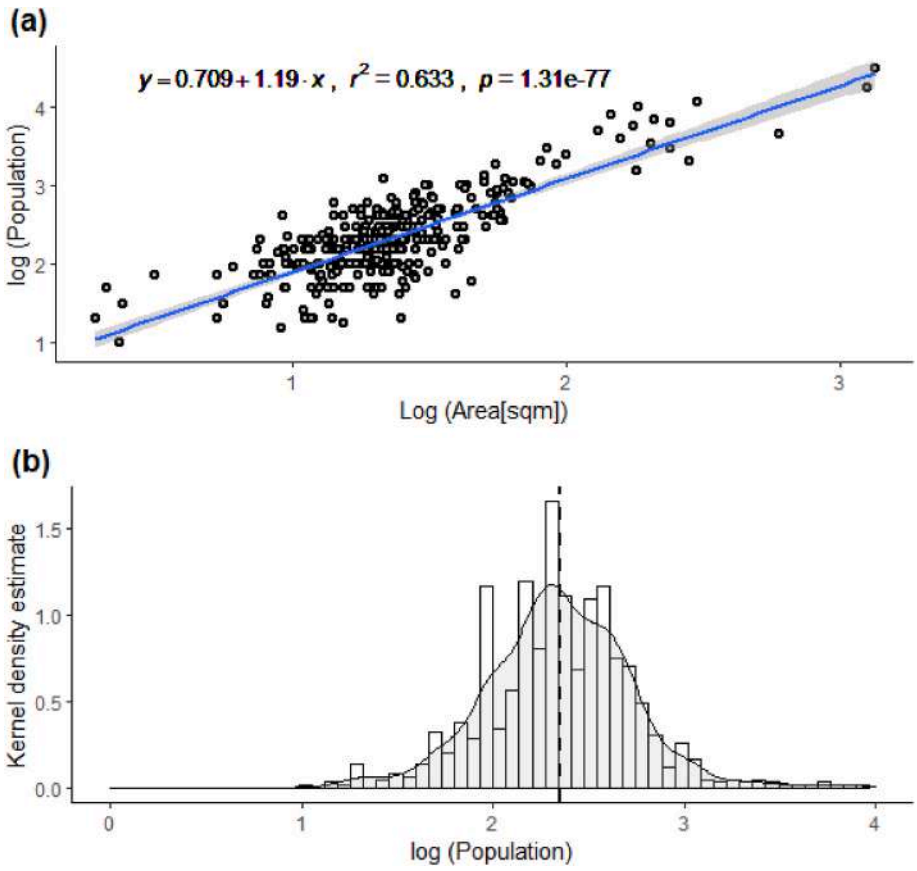

Fig. 3. (a) Fitting a linear regression model between the logarithm of the digitized area and the population as extracted from the PEF map and the survey, respectively (altogether 349 observations); (b) histogram of the logarithm transformation of the population according to the PEF (349) and predicted (515) observations (altogether 864 settlements). The overall PEF and predicted populations were 216,891 and 157,411, respectively. Altogether, a total population of 374,302 with mean, median, standard deviation, minimum and maximum of 432, 216, 1,438, 10 and 31,500, respectively.

Table 2
Statistics summary describing the fitted linear regression model (Fig. 3a).

Residuals:				
Min	1Q	Median	3Q	Max
−1.06530	−0.19053	0.03575	0.21377	0.78566
Coefficients:				
	Estimate	Standard error	t value	Pr (>|t|)
(Intercept)	0.70874	0.06811	10.40	<2e-16
Log (Area)	1.18805	0.04852	24.48	<2e-16

Residual standard error: 0.3109 on 347 degrees of freedom.
Multiple R^2: 0.6334, Adjusted R^2: 0.6323.
F-statistic: 599.5 on 1 and 347 DF, p-value: < 2.2e-16.

3.2. General statistics of the population and area by the PEF maps

Table 3 presents general statistics given the whole study area is divided into subregions representing all 26 sheets of the PEF map (Fig. 1). The most populated regions are included in sheets XI, I, XIX, and XVII, with populations of 52, 58, 63, and 64 (people per 1 sq km), respectively (TP/TA in Table 3). The lowest populated regions are in sheets XXIV, XVIII, XXV, and XV, with 0, 1, 2, and 3 (people per 1 sq km), respectively. The latter are those located in southern and eastern Palestine, where the climatological conditions are severe and water availability is poor, thus limiting the ability of societies to survive and sustain themselves. The regions with the largest ratio between the populated area and the total area are presented in sheets XIX, XI, and I, with 0.36%, 0.39%, and 0.46%, respectively, while the regions with the lowest populated area/total area ratios are in sheets XVIII, XXIV, and XXV, with 0%, 0%, and 0.02%, respectively. As it is in the case of population per 1 sq km, the least settled areas in terms of permanent settlements were in the south and east of Palestine. There were no permanent settlements in the area represented in sheets XXII, XXIII, and XXVI.

3.3. The population within the administrative boundaries of Ottoman Palestine

Grossman (2007, 2012) portrays the administrative division of Palestine based on the Ottoman yearbook of H. 1288 (1871–1872; Fig. 5). The number of surveyed settlements appearing in the PEF maps that are included within the boundaries of Ottoman Palestine is 697 (out of 864). The total, mean, median, minimum, and maximum of the population is 336,996, 482.8, 238.5, 14, and 31,500, respectively. Out of the total population, 127,886 people resided in the municipal towns—that is ~38% of the population—whereas ~62% resided in the rural regions. It is to be stressed, however, that these figures consider only the population of the permanent settlements and do not include an estimate of the Bedouin population or any other tribal element. Fig. 5 also presents the density of the population classified into the Ottoman administrative districts ('Nachyot'), after Grossman (2012). Naturally, the administrative regions surrounding the large towns, such as Jerusalem, Acre, Jaffa, and Nablus, are the densest. This is also true, although to a lesser extent, for regions around Gaza, Nazareth, and Haifa. Nevertheless, one can notice rural regions that are also relatively dense, such as the Galilee, Judea, and Samaria. On the other hand, there are prominent regions that are sparsely populated, such as the lowlands between Jaffa and Haifa, the Jordan Valley from the Dead Sea to Beisan, and the southeast-extending corridor between Jaffa and Beit Jibrin.

3.4. Spatial analysis of the data

The complete area covered by the PEF map was gridded into bins of 6 × 6 km (Fig. 6). Fig. 6a presents the number of settlements per bin. The

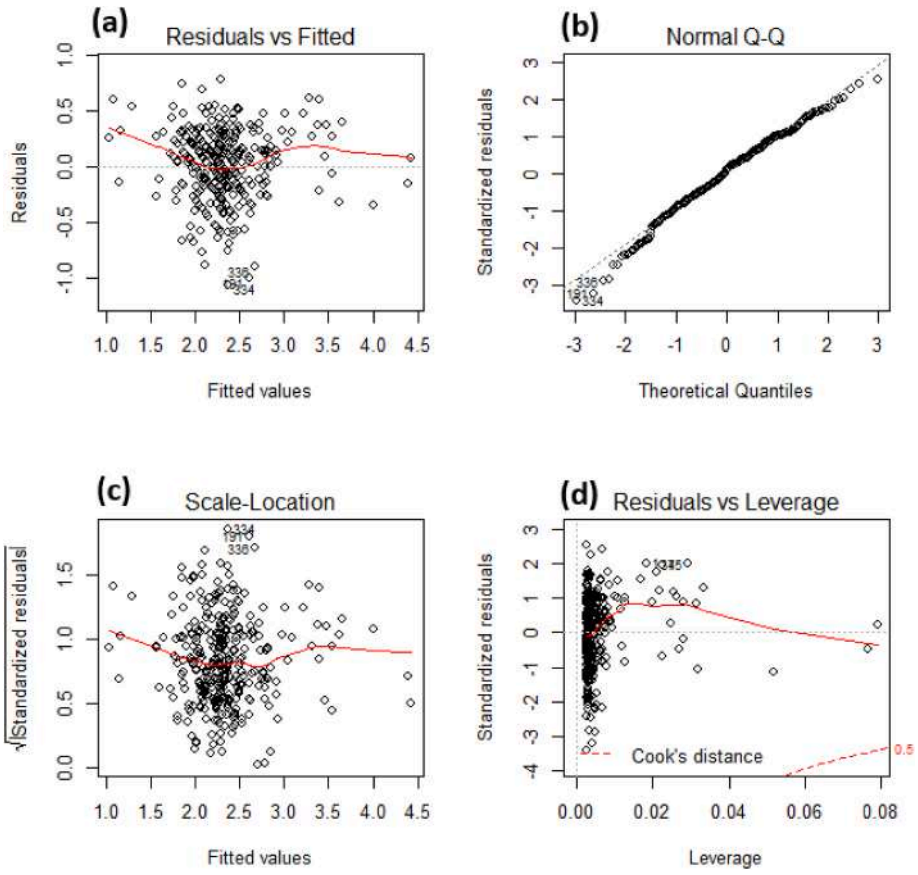

Fig. 4. Diagnostic plots of the fitted linear regression model (presented in Fig. 3a).

Table 3
The statistics of the population divided according to the 26 PEF map sheets. Columns: **TA**—total area (in sq. km, excluding the area of seas and lakes); **NS**—number of settlements; **TAS**—total area of settlements (in sq. km); **TA/TAS**—ratio of settlements' area out of total area; **MAS**—mean area of settlements; **XAS**—maximum area of settlements; **TP**—total population following the estimations of the statistical model; **TP/TA**—population per 1 sq. km; **MPS**—mean population of settlements; **XPS**—maximum population of settlements. Notable is the inclusion of Bir es Seba as a single settlement within sheet XXIV. This location was re-founded only around ~1900 (Avci, 2009; Meir, 1992) but is included as a municipal area in Barron (1923) and consequently, for comparison purposes, is listed in this table.

No.	Sheet	TA	NS	TAS	TAS/TA	MAS	XAS	TP	TP/TA	MPS	XPS
1	I	149	33	0.68	**0.46**	0.02	0.16	8585	**58**	260	3000
2	II	550	91	1.76	0.32	0.02	0.05	19200	35	211	1000
3	III	514	48	1.29	0.25	0.03	0.16	19033	37	397	6420
4	IV	804	60	1.56	0.19	0.03	0.40	19034	24	317	4550
5	V	803	40	1.44	0.18	0.04	0.12	27070	34	677	5660
6	VI	657	34	1.06	0.16	0.03	0.19	10751	16	316	2000
7	VII	93	4	0.09	0.10	0.02	0.04	646	7	162	300
8	VIII	957	54	1.44	0.15	0.03	0.08	15869	17	294	2500
9	IX	686	34	0.81	0.12	0.02	0.05	7336	11	216	512
10	X	272	8	0.15	0.05	0.02	0.04	1387	5	173	431
11	XI	959	98	3.69	**0.39**	0.04	0.20	49388	**52**	504	11,500
12	XII	669	15	0.51	0.08	0.03	0.17	5571	8	371	2297
13	XIII	511	29	0.94	0.18	0.03	0.14	24073	47	830	8000
14	XIV	961	107	3.25	0.34	0.03	0.11	32640	34	305	1449
15	XV	614	8	0.22	0.04	0.03	0.06	2129	**3**	266	700
16	XVI	831	43	2.01	0.24	0.05	0.12	21944	26	510	1500
17	XVII	964	100	3.30	0.34	0.03	0.90	61806	**64**	618	31,500
18	XVIII	545	1	0.02	**0.00**	0.02	0.02	300	**1**	300	300
19	XIX	344	10	1.24	**0.36**	0.12	0.84	21762	**63**	2176	17,480
20	XX	966	27	0.87	0.09	0.03	0.09	8956	9	332	1072
21	XXI	967	18	0.70	0.07	0.04	0.12	16022	17	890	10,000
22	XXII	249									
23	XXIII	190									
24	XXIV	744									
25	XXV	532	2	0.10	**0.02**	0.05	0.06	800	**2**	400	450
26	XXVI	77									
	Total	15608	864	27.13	0.18			374302	25.9		

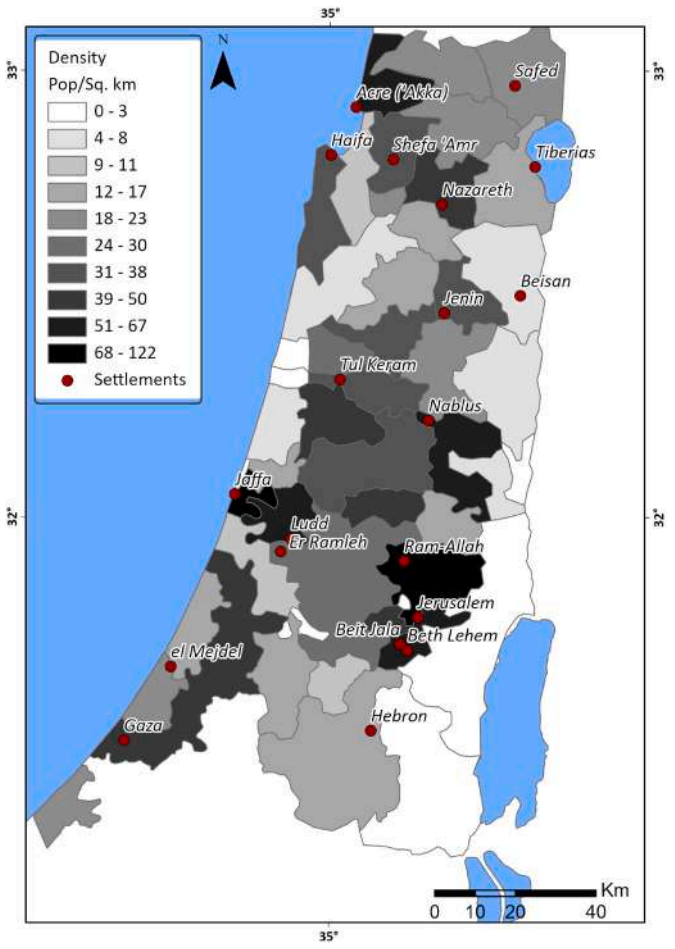

Fig. 5. The density of population per sq km classified according to the administrative district division of the H. 1288 (1871 AD) Ottoman yearbook (after Grossman, 2012).

regions with the largest number of settlements are in southern Lebanon (close to Tyre), the southern area of the Samarian Hills (around Nablus), and the northern area of the Judean Hills (around Jerusalem and Beth Lehem). The regions with no permanent settlements at all are those in the northern Negev and along the Arabah Valley between the Dead Sea and the Sea of Galilee. Unsettled regions existed also along the Mediterranean coast and, to a lesser extent, in the Lower Galilee. Dense regions along the coast are present in the environs of Acre and Jaffa. In terms of total settled area per bin, the results are slightly different. In the north, the areas surrounding Acre, Safed, and Nazareth adjoin the region close to Tyre. At the center of the map, the whole region between Jenin and Beth Lehem is recorded as being a relatively large and settled area, and in the south, it is the Hebron region as well as the area extending between Gaza and Ludd (Fig. 6b).

Fig. 7 presents the results of nearest-neighbor and density-based clustering analyses. As seen also in Fig. 6, the most clustered regions are in southern Lebanon (close to Tyre) and in the Judean and Samarian Hills, with more than three neighbors per settlement (Fig. 7a). Using a search radius of 2500 m, one can identify several settlement clusters marking the mostly densely populated regions at the time. Altogether, 16 clusters of settlements can be detected around settlements, e.g., Gaza (Cluster ID 2); el Mejdel (1); Beth Lehem, Jerusalem, and Ram-Allah (15); Ludd and er Ramleh (10); Jaffa (6); Nablus and Tul Keram (16); Tantura (5); Nazareth (4); Shefa ʻAmr (3); Acre (7); Safed (12); and Tyre (11) (Fig. 7b).

4. Discussion

4.1. Population estimates

The estimated population in the second half of the 19th century was ~375,000 and ~335,000 people within the PEF map boundaries and the administrative boundaries of Ottoman Palestine, respectively. These estimates are based on the settlement's delineation as marked on the PEF maps, as well as the population estimates the surveyors made for 349 settlements out of 864. Naturally, the resulted polygons representing the settlements are subjected to various potential errors deriving from the production process of the map, the drawing of the

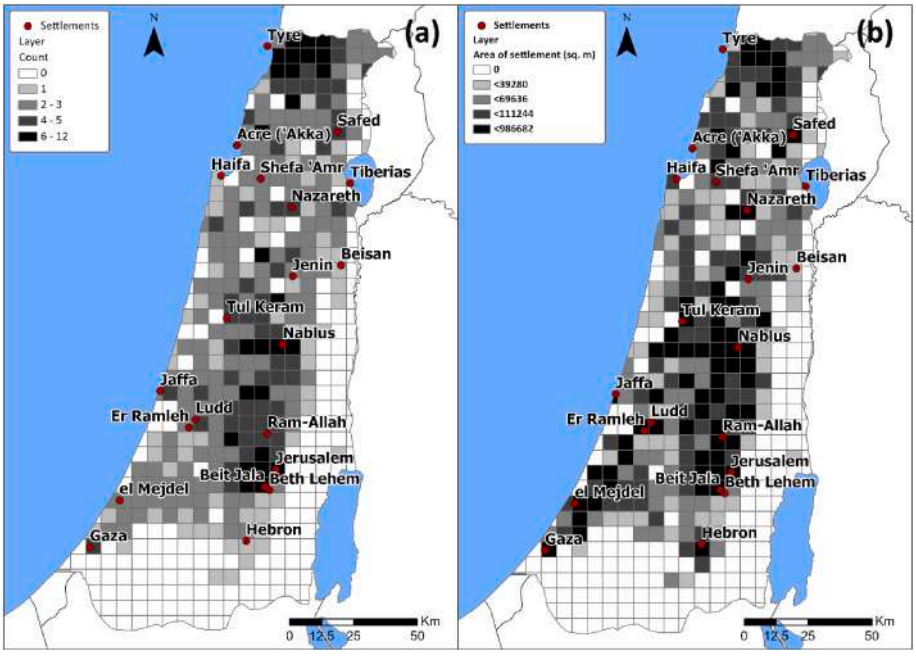

Fig. 6. Density of PEF settlements summarized by 6 × 6 km grid cells: (a) number of settlements per a grid cell; (b) total area of settlements (in sq. m) per a grid cell. The correlation between correlation between the number of settlements (count) and the area of settlement is moderate ($R^2 = 0.45$).

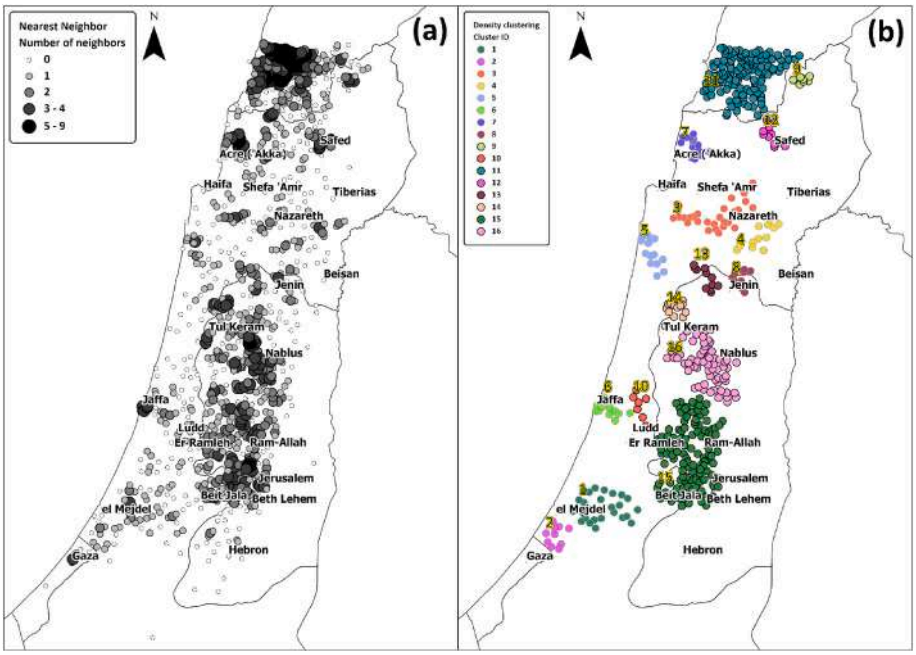

Fig. 7. Spatial patterns of the settlements using a search radius of 2500 m and autocorrelation based on the Moran I's index (see above in "Data and Methodology"): (a) neighborhood summary statistics denoting the number of neighbors for each settlement within the search radius; (b) density-based clustering yielding 16 clusters of settlements.

cartographers, map georeferencing and digitizing. The map registration error of the PEF map has already been evaluated by Levin (2006) (RMSE = 74.4 m) but as far as accuracy and completeness of the digitized area of the settlements, it is more complex. In general, these two can be verified by comparing the resulted polygons of the PEF with a reliable and accurate source, preferably one that has been produced in modern

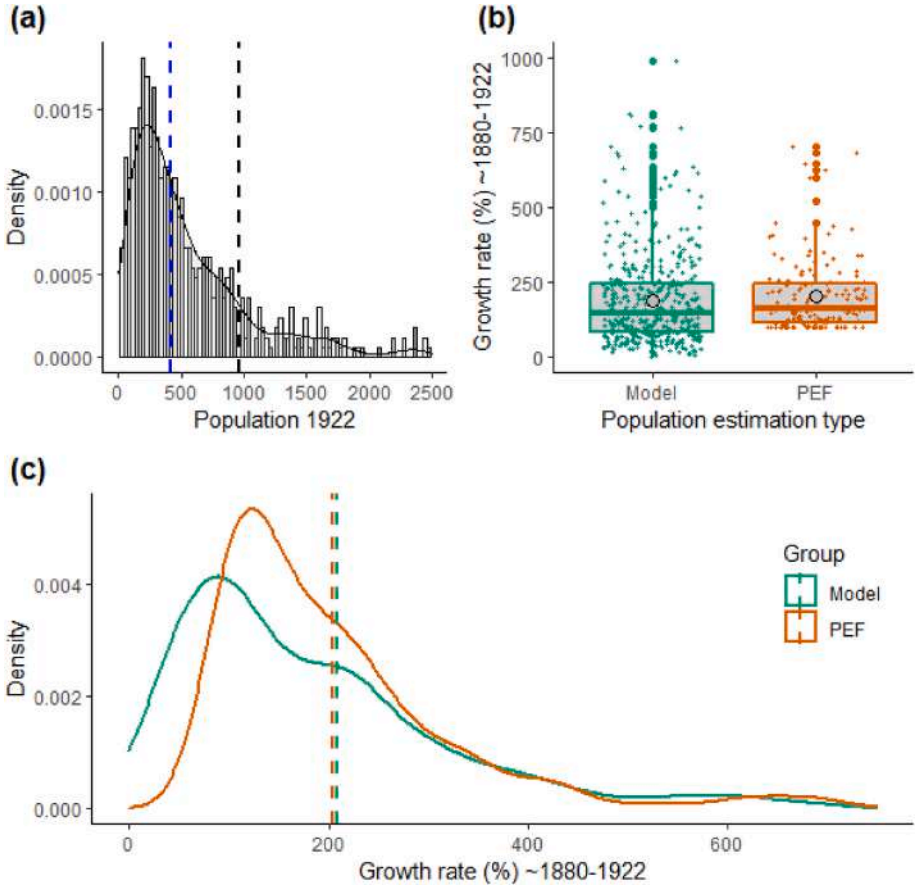

Fig. 8. (a) Population distribution according to Barron (1923). Only settlements with less than 2500 people are presented. The mean and median are noted by blue and black dashed lines, respectively; (b) boxplot of growth rate (%) between ~1880 and 1922, classified into settlements with ~1880 PEF population estimates and those with fitted model estimates; (c) density of the growth rate (%) between ~1880 and 1922, classified into settlements with ~1880 PEF population estimates and those with fitted model estimates.

standards (Leyk et al., 2005). Yet, many of the late 19th century settlements have evolved significantly during the 20th century, and their exact area at the time cannot be accurately traced for the purpose of such comparison. Thus, to test the validity of the prediction model, the results were compared to a credible and accurate subsequent census. The Ottomans carried out a partial census in the late 19th century and another, more extensive one, in 1905 (Pagis, 1997). It was, however, only in 1922, shortly after World War I, that a comprehensive census was conducted by the British authorities (Barron, 1923). The settlements attributed with population figures from Barron's (1923) census were filtered out, leaving 614 settlements out of the total of 697 settlements (Fig. 8a). Apart from the large cities, these settlements were inhabited mostly by Muslims, Christians, and Druses. Altogether, the population of these 614 settlements, as estimated for ~1880 and according the 1922 census, was 319,396 and 592,313, respectively, i.e., a total growth of 85.4%. The categorization of these settlements into those with the PEF population estimate and those with only the model prediction is presented in Table 4. Accordingly, the population growth was 93% and 75% for the former and latter categories, respectively. Seemingly, the model prediction resulted in a lower growth rate, implying that, perhaps, the model predictions are overestimated; however, when omitting the large towns, the gap between the growth rates decreases significantly to 79% and 71% for settlements with PEF estimates and model predictions, respectively—that is, a gap of only ~8%. This implies that though the population predictions of the fitted model were indeed slightly overestimated, they still correspond to the general growth rates. Considering the PEF population estimates were based merely on previous and partial estimates, the ~8% gap seems to be quite reasonable, meaning that the model's prediction is nearly accurate.

The resulting population of ~335,000 within the boundaries of Ottoman Palestine refers to permanent settlements without the Bedouins and other tribal elements. Out of this population 187,034 are based on the PEF survey and the rest are estimated results. This population assessment corresponds with some previous estimates. Grossman (2007, 2012), based on preceding sources and the Ottoman yearbook for H. 1288 (1871–1872), estimated the permanent population at 340,000–370,000 while Ben-Arieh (1986) and Schölch (1993) have evaluated 350,000–400,000 (380,000–430,000 with 30,000 Bedouins) and 400,000 (with the Negev Bedouins), respectively. Among these three, Grossman (2007) seems to be the most consistent evaluation and discusses in detail earlier population estimates such as those by Frankenstein (1944, based on Cuinet 1896), the British consul Werry (~1839), the French Ministry of Foreign Affairs (1847), the dragoman of the Prussian consulate Rosen (1849), and the American consul Jamal (based on Robinson & Smith, 1856), with estimates of 106,000 Arabs, 239,000 (except the Galilee), 250,000 (only Sanjaks of Jerusalem and Nablus), 293,084, and 365,000 (108,000 in the Galilee), respectively. Other estimations are of (Amiran & Shahar, 1961), McCarthy (1990) and Gilbar (1987), with estimates of 450,000–500,000, 440,000 and 411,000, respectively while (Abir, 1975) and (Peters, 1984) estimated the population size as much lower numbers of 145,600 (only for the Sanjak of Jerusalem) and 92,300 Arabs (in the Jewish settlement areas), respectively.

Once the estimate of ~335,000 in ~1880 has been established, one can examine the population growth rate between ~1880 and 1922. The distributions of the settlements' growth rate (in percentage) during these years are presented in Fig. 8b and c. For the settlements with the PEF estimates, the minimum, 1Q, median, mean, 3Q, and maximum growth rates are 100%, 115.9%, 164.5%, 203.7%, 245.2%, and 700%, respectively, while the same statistics for the settlements with the model predictions are 1.63%, 84.98%, 152.7%, 208.6%, 249.8%, and 1771.4%. Accordingly, the latter settlements have a slightly broader inter-quartile range (1Q–3Q) than the formers. Both have almost similar median and mean growth rates, as well as a distribution skewed to the right. This means that, along with settlements with a purported low growth rate (belonging to the 1Q), the model contains also large outliers, implying a growth rate between several hundred percent and more than a thousand. Yet, as the 3Q of both distributions is almost identical, one can consider the large outliers (4Q) of both distributions as very high regardless of the exact value. Thus, considering the growth rate is based on estimates or predictions (PEF or model) and may have biases, the inspection of the growth rate in terms of quartiles is preferred and may compensate for the shortcomings of such potential distortions.

Table 4
Growth rates of the population between ~1880 and 1922 of various groupings of settlements. Notably, as opposed to the 1922 values, the ~1880 values are rough approximations.

	No.	Pop.1880	Pop.1922	Growth (%)
Total number of settlements with 1922 population	614	319,396	592,313	85
Settlements with 1922 population & PEF estimate	164	174,087	337,121	93
Settlements with 1922 population & model prediction	450	145,309	255,192	75
Settlements with 1922 population & PEF estimate (without the large cities)	147	48,727	87,455	79
Settlements with 1922 population & model prediction (without the large cities)	446	142,650	244,441	71

4.2. Spatial patterns

The spatial distribution of the population throughout Ottoman

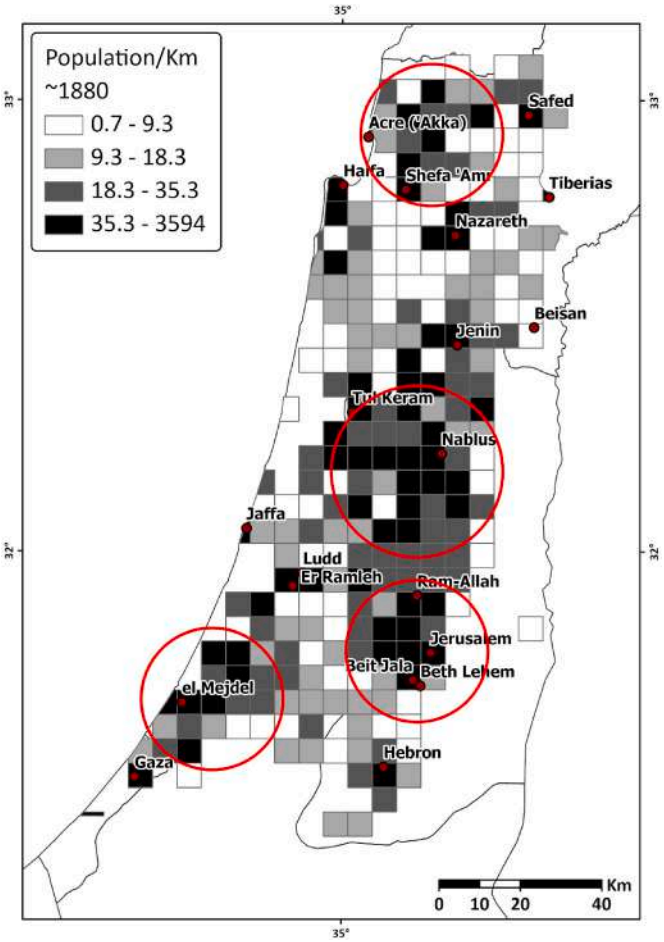

Fig. 9. Population per 1 sq km in ~1880, presented by 6 × 6 km bins.

Palestine in ~1880 is displayed in Fig. 9 using 6 × 6 km bins. The population per sq km in each grid cell is summarized and categorized into quartiles. Not surprisingly, cells including municipal towns are the densest regions, e.g., Acre, Jerusalem, Jaffa, Tiberias, and Gaza, with 3,594, 897.4, 846.3, 531.3, and 527.7 people per km, respectively. Other than the municipal towns, few regions are attributed with denser population. The four larger, marked by red circles, are in the northern Galilee, Samaria (around Nablus) and Judea (around Jerusalem), and in the vicinity of el Mejdel. Additionally, dense populations are presented in the vicinity of Nazareth, Haifa, Jenin, Ludd, and er Ramleh. Most of the dense population ratios in these regions coincide with the results in Fig. 5 and the clustering patterns of the settlements presented in Fig. 7. These results are in agreement with the spatial trends suggested by (Amiran, 1953) interrogating the settlement pattern, and also by (Amiran & Shahar, 1961; Ben-Arieh, 1981) examining the urban geography of 19th century Ottoman Palestine.

The regions along the coast between el Mejdel and Haifa (excluding the Jaffa region), the Jezre'el Valley, the regions west of Tiberias and along the Jordan Valley between the Dead Sea and Beisan, and the northern Negev were almost entirely unpopulated. Some of these allegedly unpopulated regions were occupied by tribal groups and nomads that were not accounted for in this analysis, although they were mentioned by Barron (1923) and discussed in previous studies (Kark & Frantzman, 2010; Levin et al., 2010). Towards the late Ottoman and during Mandatory periods, Muslims have gradually settled in the peripheral regions in the coastal plains (Frantzman & Kark, 2013) as well as other unpopulated regions such as Jezre'el Valley (Galilee & Kark, 2017).

5. Conclusions

The spatial distribution of the settlements of Ottoman Palestine toward the end of the 19th century was examined using the PEF map and GIScience techniques. From the PEF map, 864 settlements were digitized and extracted. Of these, 697 existed within the boundaries of Ottoman Palestine. Using a prediction model, the total population was estimated as ~375,000 in the entire region of the map and ~335,000 within the boundaries of Ottoman Palestine. The spatial distribution of the settlements was clustered, and it was found that the most densely populated regions were around municipal towns, but also in the Galilee, Samaria, Judea, and the southern coastal plain. Other regions, such as the coastal plain between Jaffa and Haifa (excluding the Jaffa itself), the Jezre'el Valley, the region west of Tiberias, the area along the Jordan Valley between the Dead Sea and Beisan, and the northern Negev were almost entirely devoid of permanent settlements. The spatial pattern of the settlements in late Ottoman Palestine have been studied before (Amiran, 1953; Amiran & Shahar, 1961; Grossman & Katz, 1992) but this study demonstrates for the first time a quantitative analysis using GIScience.

This approach is a new methodology for estimating the population of Ottoman Palestine which adds theoretical knowledge to the existing estimations as well as methodological contribution. Most of the existing population estimations are based on textual sources. Cross-correlation of the population estimation achieved in this paper (~335000, within Ottoman Palestine) with previous assessments strengthen the hypothesis that the population in late 19th century was nearly 350000. Given this value, the phrase presented at the beginning of the paper and erroneously attribute to Israel Zangwill seems to be weak. From the methodological point of view, this paper advances significantly the study of past scenarios using GIScience and historical visual sources. As the scientific discipline of historical geography seeks for new research horizons (Zohar, 2020) such contributions may lead the way.

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Author statement

Motti Zohar: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing.

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