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Reconstructing nineteenth century landscapes from historical maps—the Survey of Western Palestine as a case study

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ABSTRACT

Geographic information systems allow the extraction and quantitative analysis of information from historical maps. The aims of this research were to examine the completeness of information represented on the 1881 Palestine Exploration Fund (PEF) map, to quantitatively reconstruct the landscape of nineteenth century Palestine and to explore whether spatial patterns in land cover/land use can be partially explained statistically by physical and human factors. Using historical aerial photos, we concluded that most of the major past landscape features were indeed shown on the PEF map, with an average overall correspondence of 53%. Forests and Mediterranean maquis were more abundant at distances greater than 2 km from towns and villages. Specific land cover/land-use types were associated with certain soil types, topographic regions and rainfall thresholds. In conclusion, the 1881 PEF map can serve as a reliable reference for understanding the land cover/land-use patterns of nineteenth century Palestine.

KEYWORDS

GIS; historical maps; land cover; land use; aerial photos; Palestine

1. Introduction

Historical maps are a common tool used by historians, archaeologists and geographers to reconstruct past landscapes, places and customs (Andersen, Crow, Lietz, & Stearns, 1996; Kark, 1988; Skånes & Bunce, 1997). In the last 10 to 15 years, the development of different geographic information system (GIS) programmes has opened new avenues to extract and quantitatively analyse spatial information from historical maps, thus allowing the reconstruction of past landscapes (Fensham, 2008; Gregory, Bennett, Gilham, & Southall, 2002; Grossinger, Striplen, Askevold, Brewster, & Beller, 2007; Knowles & Hillier, 2008; Levin, 2006; Levin, Elron, & Gasith, 2009; Petit & Lambin, 2002; Sanderson & Brown, 2007).

Palestine offers a wealth of historical cartographic sources due to its long human history and world-wide interest in the region. Located between three continents and hosting a wide range of climates, soil types and varied topography within a small area contribute to the region's status as a biodiversity hotspot (Danin, 1988). For many centuries, Palestine was a pivotal country due to its geographical location, along the trade routes between Europe, the Middle East and the Far East that generated both wealth and political power. Consequently, the area has been subject to political turmoil, wars, conquests and population migration which have contributed to the modification of the natural and cultural landscape (Paz, 1980; Thirgood, 1981).

The nineteenth century is considered as the beginning of the modern era in the Middle East in general and Palestine in particular. The 1830s began with the gradual decline of the Ottoman Empire

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Supplemental data for this article can be accessed here.

(Feroz, 2000). The Capitulation treaties, which were imposed on the Ottomans by the European governments as part of the competition between the European powers, facilitated foreign investment, development and exploration of Palestine (Ben-Arieh, 1985; Margalit, 1965; Shamir, 1985). The process of development that started was also followed by a growth in population, mainly due to Arab and Jewish immigration, which fostered further development with the construction of new infrastructure and new settlements (Gerber, 1982; Kark, Denecke, & Goren, 2004; Naveh, 1981; Reifenberg, 1950). While in 1875, the estimated population in Palestine was 450 000, in 1914, the population had already reached 800 000 inhabitants, and at the end of 1947, the population of Israel, the West Bank and Gaza reached nearly two million inhabitants (Bachi, 1977). Between 1877 and 1922, 69 new Arab villages and 58 new Jewish villages were founded (Frantzman, 2010; Schölch, 1985). Moreover, far-reaching changes in the landscape took place after the creation of the State of Israel in 1948. These changes included mobilisation of the population (displacement of the local Arab population and new waves of Jewish immigration); the depopulation and destruction of Arab villages; the foundation of new Jewish settlements and towns and widespread afforestation efforts (Falah, 1996; Tal, 2013).

The renewed foreign interest in Palestine in the nineteenth century was bolstered by competing Imperial powers, especially Britain, France and Germany, which during this time gathered information about the land and its people for future Imperial aspirations (Burrows, 1986; Christopher, 1990). This led to various mapping efforts (see Ben-Arieh, Ahrnson, & Labaski, 2001; Rubin, 2001), generating a wealth of valuable information about past land cover, when remnants of land cover features such as different types of forests, sand dunes and wetlands were still present (Levin, 2006; Reifenberg, 1950; Thirgood, 1981).

The Survey of Western Palestine of the Palestine Exploration Fund (PEF) (Conder & Kitchener, 1871–1877) is recognised for its planimetric precision and accuracy by modern standards (Levin, 2006). The survey was conducted by a British research society with a purpose to study all the aspects of Biblical Palestine and the Levant area (Moscrop, 2000). The PEF-appointed employees from the British Royal Engineer Corps who were commissioned to produce the survey map and accompanying literature. The PEF survey map of Western Palestine was prepared between the years 1871 and 1877 and was published in 1881, a year before the first wave of Zionist immigration to Palestine began. The map depicts the landscape in great detail (scale of 1:63 360) and includes built-up areas and different natural features. The map is accompanied by three memoir books (Conder, Kitchener, Palmer, & Besant, 1881), which describe the map in detail, and an additional book on the flora and fauna of Palestine (Tristram, 1884). The PEF map provides a rare and unique glimpse of Palestine's "pre-industrial" landscape. Several past works have used the PEF survey map as a source to depict nineteenth century Palestine (Levin, 2006; Levin et al., 2009; Margalit, 1955). The aims of the present research were as follows:

- To examine the completeness of information represented on the PEF map.
- To digitally reconstruct the landscape of nineteenth century Palestine.
- To explore whether spatial patterns in the land cover/land use of nineteenth century Palestine can be partially explained statistically by physical and human factors.

2. Methods

2.1. Study area

The study area covers 14 717 km^2, representing 94.3% of the total area covered by the PEF maps (Figure 1). The research area covers the present day State of Israel (between 34°10'–35°45' E and 31°13'–33°18' N), including territories beyond the 1949 armistice agreement line, namely the West Bank and part of the Gaza Strip, but excluding the Negev Desert south of the city of Beer-Sheba and the Golan Heights. The area of present day South Lebanon appearing on the PEF map is not included due to lack in present GIS data layers, which were used for statistical analysis, amounting to 5.7% of the total area of the PEF survey map.

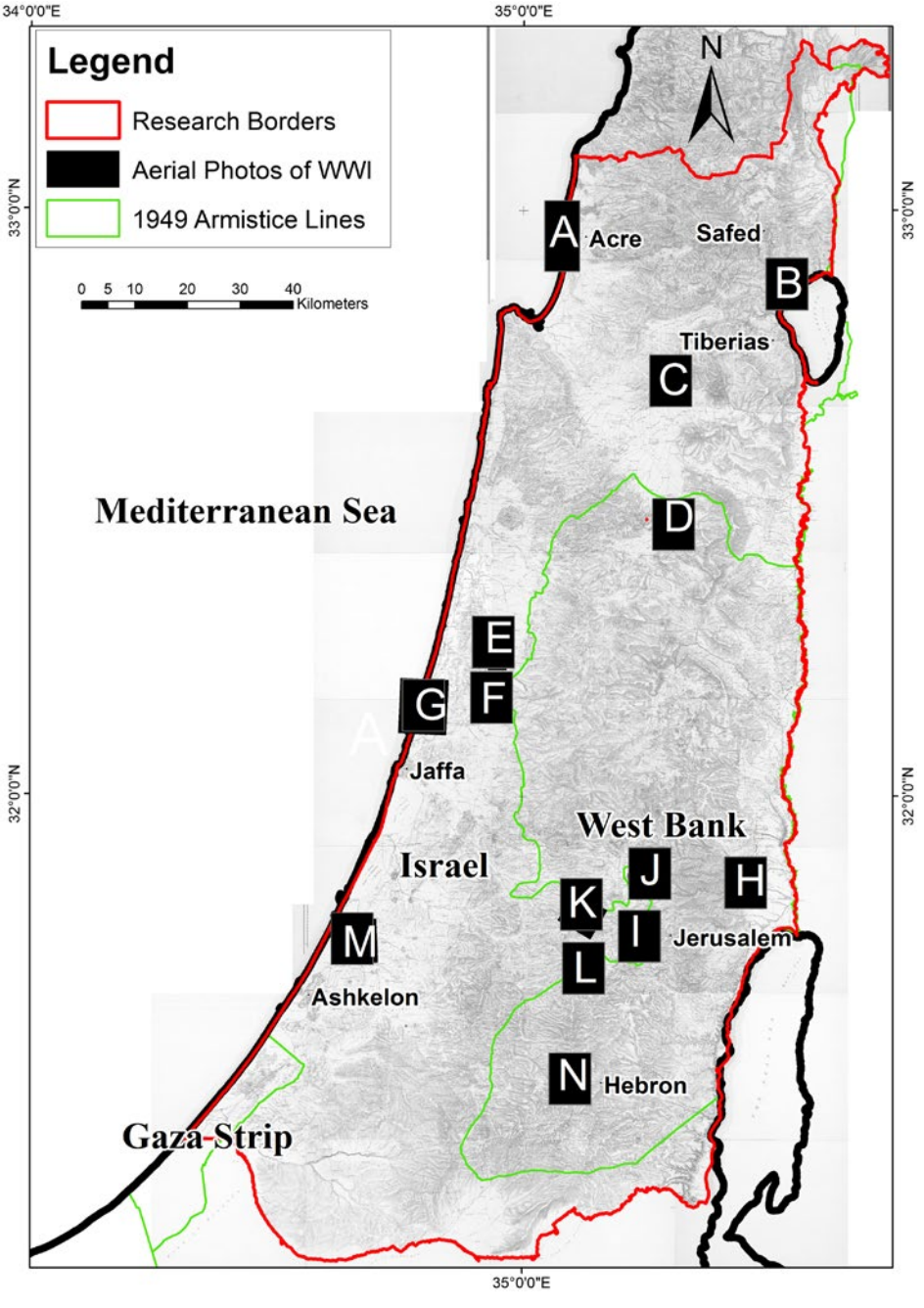

Figure 1. Study area (red) and the location of the 14 reference sites chosen to examine the level of completeness and accuracy of the PEF map by comparing it to WWI aerial photos (for more details, see Table S2). The original PEF map appears in the background.

2.2. Study sources

The PEF map sheets were geo-referenced using 123 control points of trigonometrical stations and first-order polynomial, with a root-mean-squared error of 74.4 m (for details see Levin, 2006). The PEF map depicts topography using a shading system and depicts several landscape features that were of an interest to the surveyors. The memoir books that accompany the map (Conder et al., 1881; Tristram,

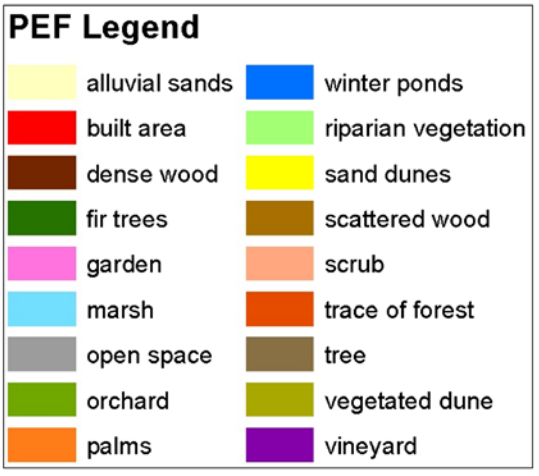

Figure 2. The wider PEF legend created and used for the purpose of digitization of nineteenth century landscape of Palestine. For more details, see Figure S2.

1884) were consulted by us to better understand the features on the map because they describe the geographical, geological, hydrological and archaeological aspects of the land and also include data on population and agriculture.

World War I (WWI) aerial photos were used to examine the completeness of land cover/land-use information represented on the PEF map. The German army acquired aerial photos between the years 1917 and 1918 for military purposes (Gavish & Biger, 1985), covering only part of the research area. As hardly any other detailed historical maps covering the entire area were created prior to WWI (Gavish, 2005; Levin, Kark, & Galilee, 2010), these aerial photos were used to verify the land cover digitised from the PEF maps (as explained below), in spite of the temporal gap of approximately 40 years separating them from PEF maps.

One of the main limiting factors for vegetation growth and for agriculture in this semi-arid climate area (prior to the development of modern irrigation systems) is the availability of water (i.e., rainfall) and soil type, whereas the region's temperature is moderate and is not a limiting factor for vegetation (Feitelson, Selzer, & Almog, 2014; Kadmon & Danin, 1997, 1999). Two additional GIS layers were therefore used as follows: mean annual rainfall (1950–1980, assuming no statistically significant changes in rainfall in the past century, following Axelrod & Gabbay, 2010) digitised by Kadmon and Danin (1999) from a 1:250 000 rainfall map; and a soil map digitised by the Israeli Ministry of Agriculture and rural development based on the map of Israel's soils, scale 1:250 000 (Dan & Raz, 1970).

2.3. Spatial analysis

2.3.1. Land cover/land-use mapping

In order to reconstruct nineteenth century Palestine landscape, we used a geo-referenced file of the mosaic PEF map (available from Levin, 2006; http://doi.pangaea.de/10.1594/PANGAEA.819656). Digitising land cover/land-use features was conducted using ArcGIS. While the PEF map is accompanied by a legend, we created a detailed legend incorporating additional features that are shown on the map but are not included on the formal legend of the PEF map, such as, individual ancient trees, traces of forests, riparian vegetation, scattered/dense wood and open space (Figure 2 & Figure S1). We classified the "level of certainty" to which a land cover/land-use category was identified (as in Grossinger et al., 2007) for each of the digitised land cover polygons. A definite identification of the class of a feature was scored as 1, a partial identification received a score of 2 and an uncertain identification received a score of 3 (Table S1 and Figure S2).

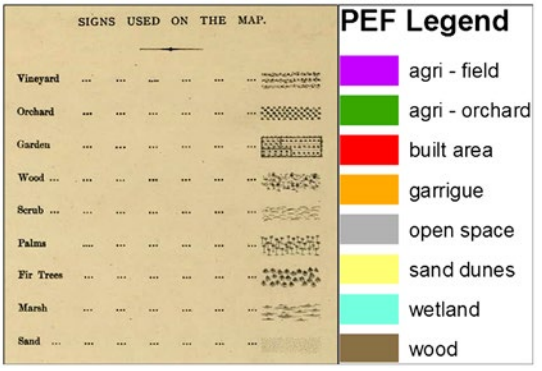

Figure 3. Original PEF legend of landscape features (left) and reduced PEF legend (right) used here to compare the land cover/land-use layers digitised from the PEF map and from the aerial photos.
Note: Agri-field (agricultural-fields, crop fields) which could be detected on the aerial photos may have existed at the time of the PEF survey, but on the PEF map, they appear as open space.

2.3.2. Map completeness

In order to assess the completeness of the information represented on the PEF map, we used WWI aerial photos. We chose 14 reference areas to compare the PEF digitised map landscape to the aerial photos (Figure 1). The reference areas were chosen based on the availability of aerial photos, aiming to represent different regions in Palestine as well as different landscape features, such as winter ponds, sand dunes, woods and scrubs.

As in an aerial photo, only general landscape classes can be identified and as it is hard to distinguish between variations of a feature (e.g., oak vs. pine wood), we created a simplified legend that included features that could be identified on both the PEF and in the aerial photos (Figure 3).

We geo-referenced the aerial photos to British 1:20 000 maps that were created between the late 1920s to the late 1940s, which are spatially more accurate than the PEF map (Gavish, 2005; Levin et al., 2010) and that are closer in time to the aerial photos. We digitised the landscape features shown on the aerial photos and analysed the correspondence in land cover between these two historical sources (PEF and WWI) in these 14 reference sites (Table 1, Table S2). For calculating the difference in the land cover/land-use composition of the PEF map and the aerial photos, we used the following formula:

$$SumAbsDiff = \sum_{c=1}^{n} |\%PEF_c - \%Aerial_c|/2 \quad (1)$$

where $\%PEF_c$ is the percentage cover of each class in the digitised PEF map, and $\%Aerial_c$ is the percentage cover of each class in the digitised aerial photo, so that the maximum possible difference can be 100%. This equation measures the correspondence between two land cover/land-use maps by measuring the absolute difference between each class derived from the PEF and the same class derived from the aerial photo. This allowed us to get a quantitative estimate of the total difference without accounting for errors that are due to geo-referencing errors. In addition, we generated confusion matrices from which we calculated the overall correspondence and the Kappa index of agreement, which expresses the proportion of correspondence above the expected correspondence due to chance (Cohen, 1960; Pontius, 2000) to examine the spatial differences in land cover/land-use patterns between the PEF map and the aerial photos in the 14 sites examined. The Kappa Index of agreement was calculated using the following formula:

$$\text{Kappa index of agreement} = \frac{overall\ accuracy - chance\ agreement}{1 - chance\ agreement} \quad (2)$$

Table 1. The results of the 14 reference areas comparing the PEF map to the aerial photos from the First World War are displayed in the following table.

					Spatial correspondence		No. of random points used to examine correspondence between landscape classes (25 in each site)			Population figures		
Sites (Figure 2)	Past name of the site (present day name)	Area (km²)	Class matching[1]	SumAbs Diff[2]	Overall correspondence (%)	Kappa index of agreement (%)	Full match	Mismatch due to land cover changes	Mismatch due to geo-referencing or mapping errors	1868 (Guerin, 1868)	1881 (Conder et al., 1881)	1922 (Barron, 1922)
A	Acre	6.0	All (5)	38.5	32	7	8	16	1	9000	N/A	6420
B	Et Tabera (Tabgha)	0.5	–3 (5)	19	73	3	12	13	0	N/A	N/A	N/A
C	Nazareth	1.2	All (3)	13	49	17	9	16	0	4950	Less than 6000	7424
D	Jenin	0.9	All (3)	2	66	42	16	0	9	Less than 2000	~3000	2637
E	El Tireh (Tira)	1.2	All (3)	33	27	–22	6	17	2	~1000	N/A	257
F	Kefr Saba (Kfar Saba)	5.1	–1 (6)	36.5	25	–6	10	15	0	800	N/A	546
G	El Jelil (Herzeliya)	21.2	–2 (7)	21.5	63	37	16	6	3	N/A	N/A	154
H	Eriha (Jericho)	5.0	–1 (6)	40.5	41	–1	10	15	0	N/A	300	1919
I	Jerusalem	5.1	All (4)	27.5	46	21	14	11	0	~18 000	15 000–20 000	62 578
J	Er Ram (Al-Ram)	2.5	All (3)	2	88	9	19	0	6	N/A	N/A	624
K	Kuryet el Enab	7.6	All (4)	22	68	16	14	1	10	N/A	N/A	548
L	Bittir (Battir)	1.7	All (4)	23.5	56	–11	16	3	6	350	N/A	542
M	Esdud (Ashdod)	6.7	All (5)	8.5	77	64	21	4	0	~1800	N/A	2566
N	Hebron	2.0	All (3)	19.5	36	–1	7	3	15	7000	10 000	16 577

[1]Do the classes found on both the PEF and aerial photos match? "All" = all classes match; "#" = no. of classes that do not match; the number in parentheses indicates the total number of landscape classes
[2]Sum of the absolute difference of total land cover/land use % of area.

Finally, we created a stratified sample of random points using ArcGIS 10.1, with 25 random points in each of the 14 sites (ESRI, 2014). For each of these points, we extracted the land cover from the PEF map and from the aerial photos. We then examined whether the land cover types matched, and if not, whether the mismatch could be attributed to land cover/land-use change, or to geo-referencing, digitising or mapping errors (based on the PEF memoirs and other historical sources). We also collected information of the population in the built-up areas which were found in the 14 sites in three different periods (Table 1) (Barron, 1922; Conder et al., 1881; Guerin, 1868).

2.3.3. Physical and human factors of landscape patterns

To ascertain whether spatial patterns in the land cover/land use of nineteenth century Palestine could be partially explained by physical and human factors, we analysed three physical factors (soil type, annual rainfall and topography) and one human factor (distance from built-up areas). The average annual rainfall was divided into 13 categories of 100 mm/year each. The soil type layer included 15 soil classes (Survey of Israel, 2011). We classified the study area into three broad topographic regions: Coastal Plain region between 0 and 200 m, Mountain region above 200 m and the Inner Valleys region below sea level (0 m), using a digital elevation model (DEM) (Figure S3). The affinity of a certain land cover class to each of the three topographic regions was determined using the following formula:

$$Affinity_{region} = \frac{Class\%}{Topo\%} \tag{3}$$

where *Class%* represents the per cent area of a certain land cover class within a certain topographic region out of its cover in the entire study area, and *Topo%* represents the per cent area of that topographic region out of the entire study area. Classes with affinity values greater than 100% in one of the topographical areas are more abundant in those areas. The spatial resolution of the DEM was 25 m, and it was originally interpolated from contour lines at vertical intervals of 10 m on 1:50 000 topographic maps (Hall, 2008). We also examined whether the distances from villages and towns shown on the PEF map could explain some of the spatial patterns of the land cover/land-use features. We divided the distances into nine distance classes, multiples of two from 0.5 to 40 km.

3. Results

3.1. Completeness of information represented on the PEF map

Overall, 18 land cover classes were identified and 11 704 polygonal features were digitised from the PEF map. Table 1 summarises the validation results of the land cover/land use (for the detailed analysis see Table S2). The average class-wise difference (using the SumAbsDiff statistic) between land cover/land use digitised from the PEF and from the aerial photos was 22%, and only four of the 14 sites examined had differences greater than 33% (Table 1, 5th column). Within the four areas with the highest summed absolute differences (Kfar Saba, Acre, Tira, and Jericho), the landscape features which changed the most were "wood" (decrease) and "open space" (increase) (Table S2). The SumAbsDiff statistic was significantly correlated with the overall correspondence statistic ($R^2 = 0.62$, $p < 0.01$; Table 1, Figure S4) and with the Kappa index of agreement ($R^2 = 0.34$, $p < 0.05$; Table 1, Figure S4).

The overall correspondence in land cover between the PEF map and the aerial photos for the 14 sites analysed ranged between 25% and 88% (average of 53%; Table 1). The Kappa index of agreement (KIA; Table 1, seventh column) ranged between −22% and 64%. Of the 350 random points, in 178 points (51%), the PEF and WWI land cover types matched, in 120 points (34%), the mismatch in land cover was attributed to actual land cover changes that took place between the 1870s and WWI, and in the remaining 52 points (15%), the mismatch in land cover was attributed to geo-referencing, digitising or mapping errors (Table 1). The mismatch in land cover due to land cover changes was correlated with the SumAbsDiff metric ($R^2 = 0.49$) and negatively correlated to the overall correspondence ($R^2 = 0.46$; Figure S4). In ten of the 14 sites examined, all classes were present in both the sources (between the PEF map and the aerial photos). In two of the remaining four sites, only one class was missing, implying

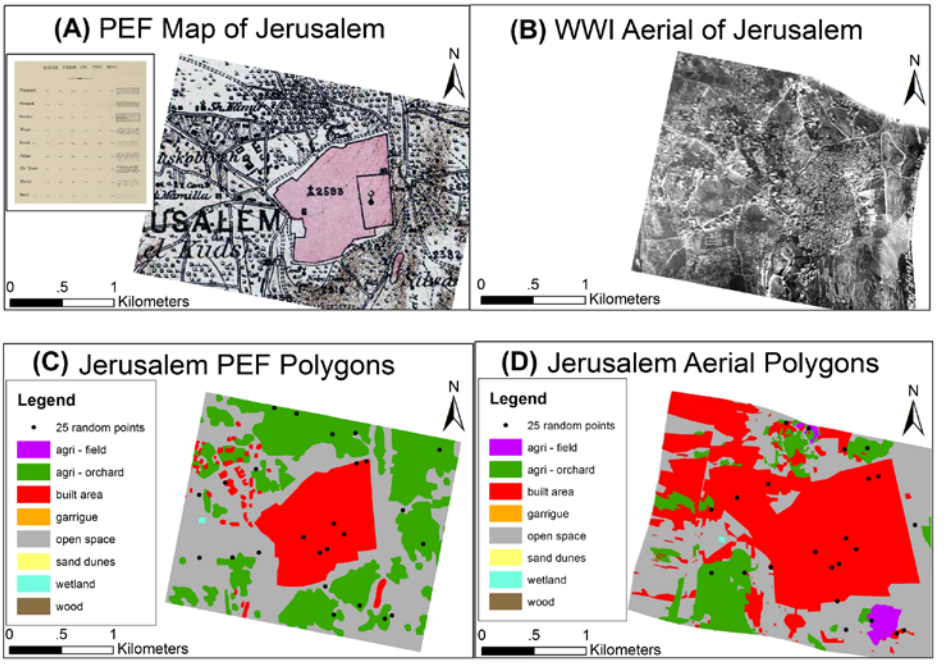

Figure 4. Landscape changes around the Old City area of Jerusalem. (A) The PEF map (1880); (B) The WWI aerial photo; (C) Digitised land cover/land use from the PEF map; (D) Digitised land cover/land use from the aerial photo.

that most of the landscape features portrayed on the PEF map were similar to the ones appearing on the aerial photos (Table 1, fourth column).

Two of the 14 sites examined are analysed here in detail, one representing a built-up area (Jerusalem and the Old City; Figure 4) and the second representing a rural area along the coast (El Jelil; Figure 5). In the Jerusalem area, the differences between the digitised layers were noticeable, with a SumAbsDiff value of 27.5% (Table 1, Figure 4; overall correspondence of 46%, KIA of 21%). In 14 of the 25 random points, the land cover types matched, whereas the mismatch in the remaining 11 points was attributed to land cover changes. In the 1880s, the "built-up area" (coloured in red) was mainly within the old city walls (square shape) with several other small buildings around it (Figure 4(a) and (c)). Forty years later, the "built-up area" had expanded outside the Old City walls, mostly towards the northwest (Figure 4(b) and (d)). The population of Jerusalem grew from 31 500 in 1880 to 62 578 in 1922 (Bachi, 1977; Barron, 1922; Ben-Arieh et al., 2001). Another clear landscape feature that changed was "agri-orchard" (coloured in green); in the 1880s, there were many areas of "agri-orchard" (Figure 4(a) and (c)), whereas by WWI, the agricultural areas around the Old City were reduced in size (Figure 4(b) and (d)).

In the El Jelil area, the differences in land cover/land use between 1880 and WWI were smaller, with a SumAbsDiff value of 21.5% (Table 1, Figure 5; overall correspondence of 63%, KIA of 37%). In 16 of the 25 random points, the land cover types matched, whereas the mismatch in the remaining points was attributed partly to land cover changes (6 of 25) and mapping errors (3 of 25). The area of "sand dunes" has expanded slightly inland. Moreover, we notice that the "wood" area has disappeared completely and was partly replaced by "garrigue" vegetation. Nonetheless, there were also similarities between the two digitised layers, and the sand dunes and the wetlands are almost identical in their location and size, indicating the completeness of the PEF map.

3.2. Nineteenth century landscape of Palestine

The total area of the PEF digitised map is of 14 717 km^2 (Figure 6). The "empty" areas (i.e., areas where no specific land cover type was shown on the map) found within the study area were termed here as

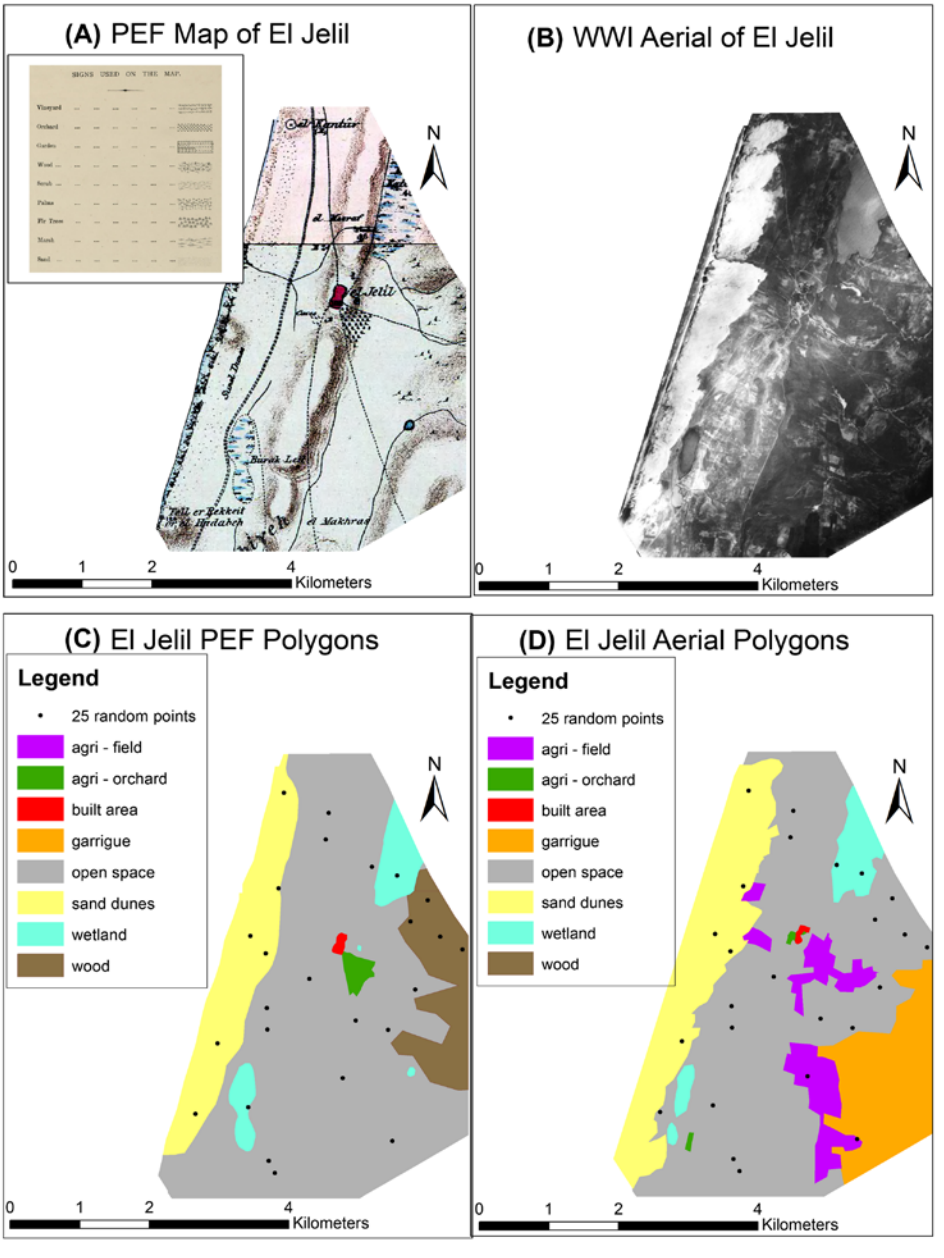

Figure 5. Landscape changes around El Jelil. (A) The PEF map (1880); (B) WWI aerial photo; (C) Digitised land cover/land use from the PEF map; (D) Digitised land cover/land use from the aerial photo.

"open space" areas, covered 11 447 km^2 (78% of the total area) (Figure 6, Table 2). Apart from "open space," the largest features in the study area were "scrub" (6.5%) followed by "scattered wood" (5.9%) and "orchards" (4.1%) (Table 2). Seven hundred and twenty-four localities (mostly villages) were found on the PEF map within the study area, comprising only 0.2% of the total area of research. The classes with the smallest areas in nineteenth century Palestine landscape were "fir trees" (coniferous trees) followed by "palms," "winter ponds" and "vineyards" (Table 2).

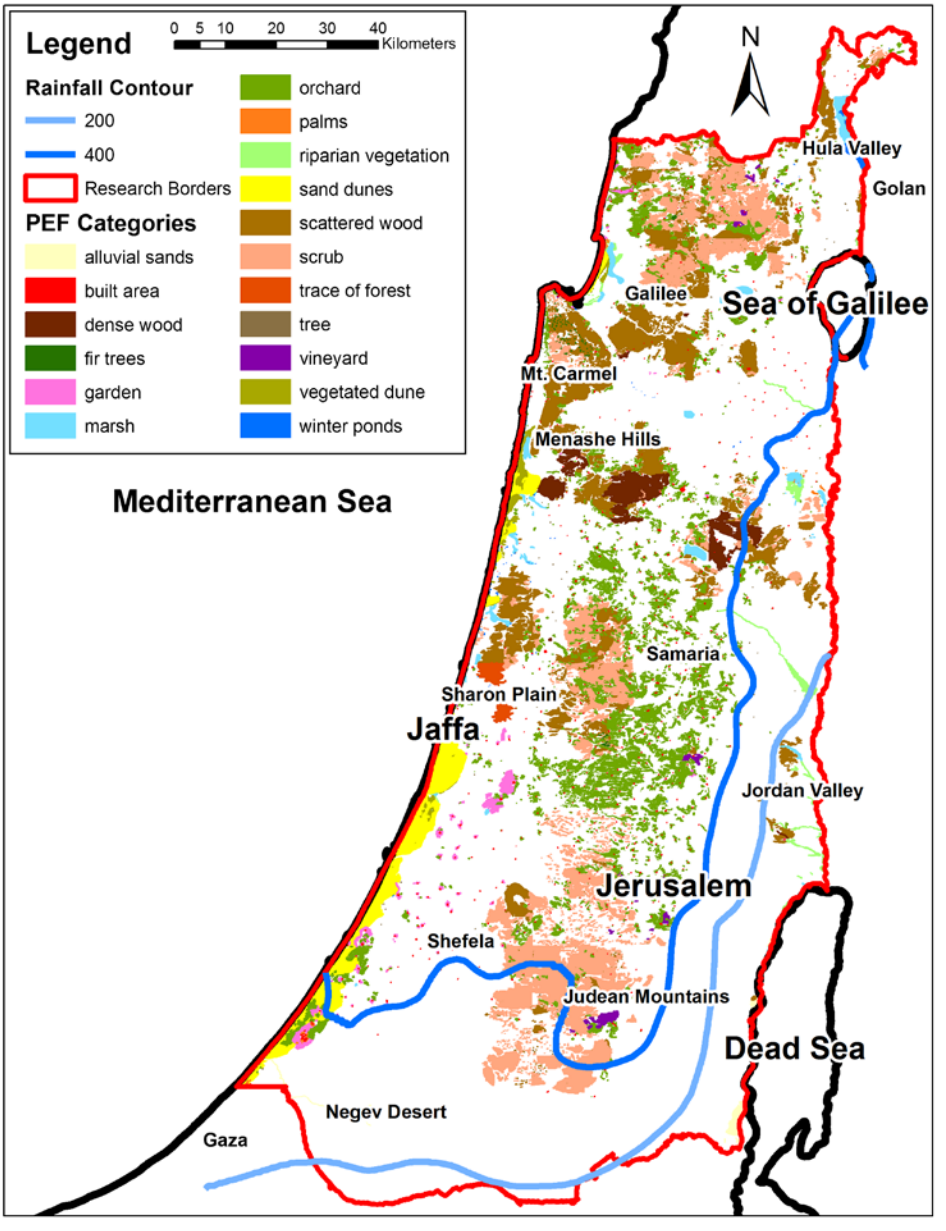

Figure 6. Digitised land cover/land-use map showing nineteenth century Palestine as was depicted on the PEF map. The different colours of the map represent different landscape features found. The two rainfall contour lines represent as follows: 400 mm/year and above is considered the Mediterranean region; between 400 and 200 mm/year is considered a transitional region; and below 200 mm/year is considered a desert.

3.3. Statistical analysis of physical and human drivers

3.3.1. Rainfall

The distribution of most of the agricultural features was restricted to areas above 400 mm/year, within the Mediterranean region (Figure 7, Table S3). Among the human-dominated landscape features, "palms" were associated with the least amount of rainfall 400–500 mm/year, mostly along the coastal dunes, whereas orchards were associated with the highest amount of rainfall (700–800 mm/year; Figure 7A, Table S3).

Table 2. Land cover classes digitised from the 1881 PEF map of Palestine, ordered by their respective area, are displayed in the following table. Non-natural classes are highlighted in grey. All values refer to the landscape categories of the wider PEF legend.

Landscape categories — wider PEF legend	Area (km²)	%	Percentage without "open space" category	Landscape categories —reduced PEF legend*
Tree	1.9	0.0	0.1	wood
Fir trees	2.8	0.0	0.1	wood
Palms	3.9	0.0	0.1	agri-orchard
Winter ponds	14.2	0.1	0.4	Wetland
Vineyard	23.8	0.2	0.7	agri-orchard
Built-up area	24.2	0.2	0.7	built-up area
Alluvial sands	25.9	0.2	0.8	sand dunes
Traces of forest	27.2	0.2	0.8	wood
Vegetated dunes	42.5	0.3	1.3	sand dunes
Riparian vegetation	63.6	0.4	1.9	wetland
Garden	66.2	0.5	2.0	agri-orchard
Marsh	83.6	0.6	2.6	wetland
Dense wood	146.5	1.0	4.5	wood
Sand dunes	314	2.1	9.6	sand dunes
Orchard	596.9	4.1	18.3	agri-orchard
Scattered wood	872.4	5.9	26.7	Wood
Scrub	960.7	6.5	29.4	garrigue
Open space	11 446.9	77.8	null	open space
Total	14 717	100	100	

*For more information, see Figure 3.

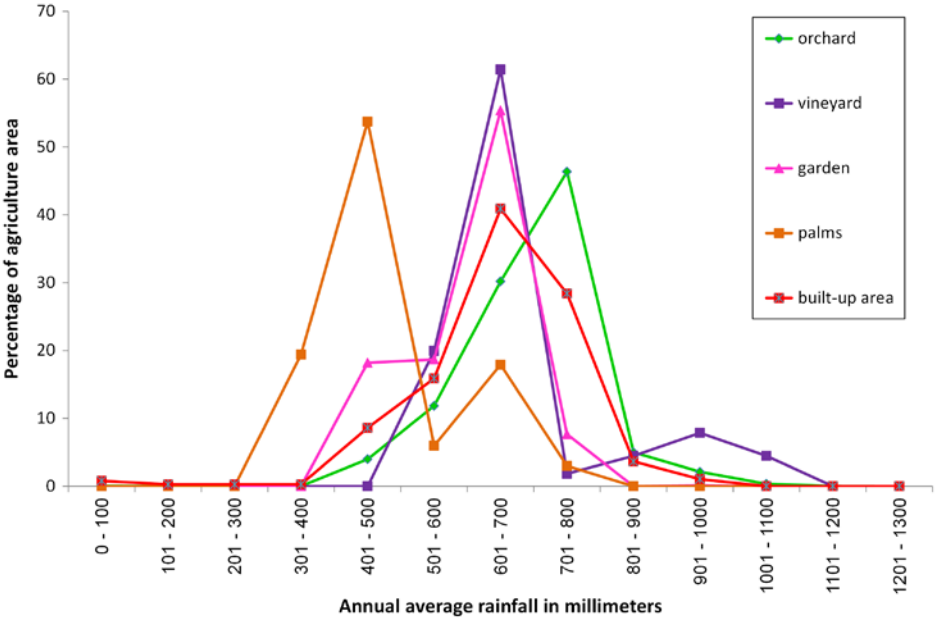

Figure 7A. The spatial distribution of built-up and agricultural areas as digitised from the PEF map, as a function of rainfall belts. Each of the land-use feature classes sums up to 100%.

When examining the peak concentration (>20%) of the different classes of Mediterranean vegetation, a gradient was found, with natural Mediterranean vegetation changing from scrub (500–800 mm/year), to scattered wood (600–800 mm/year), dense wood (700–800 mm/year) and fir trees (700–900 mm/year) with increasing rainfall (Figure 7B, Table S3).

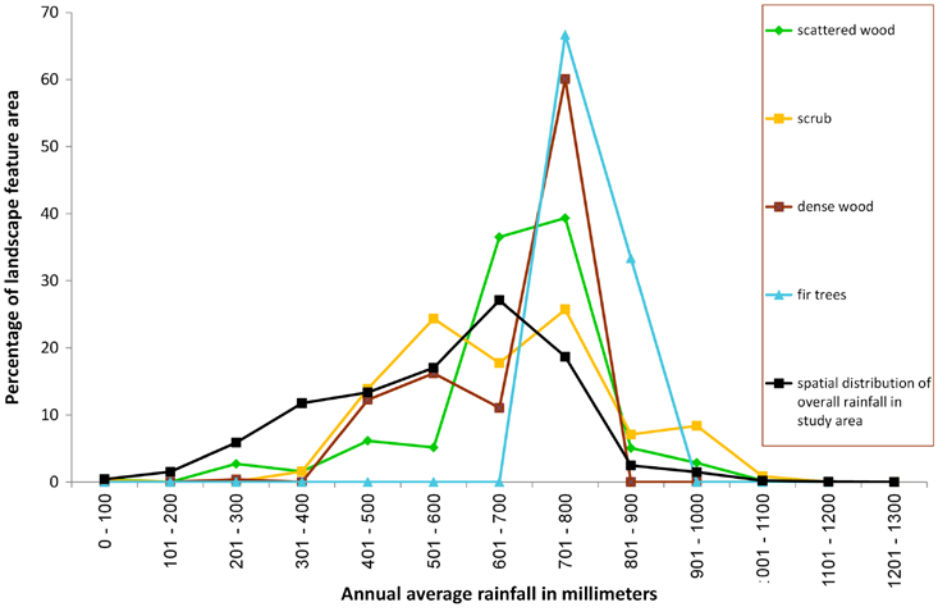

Figure 7B. The spatial distribution of natural Mediterranean vegetation as digitised from the PEF map, as a function of rainfall belts. The spatial distribution of the PEF study area is coloured in black. Each of the land cover feature classes sums up to 100%.

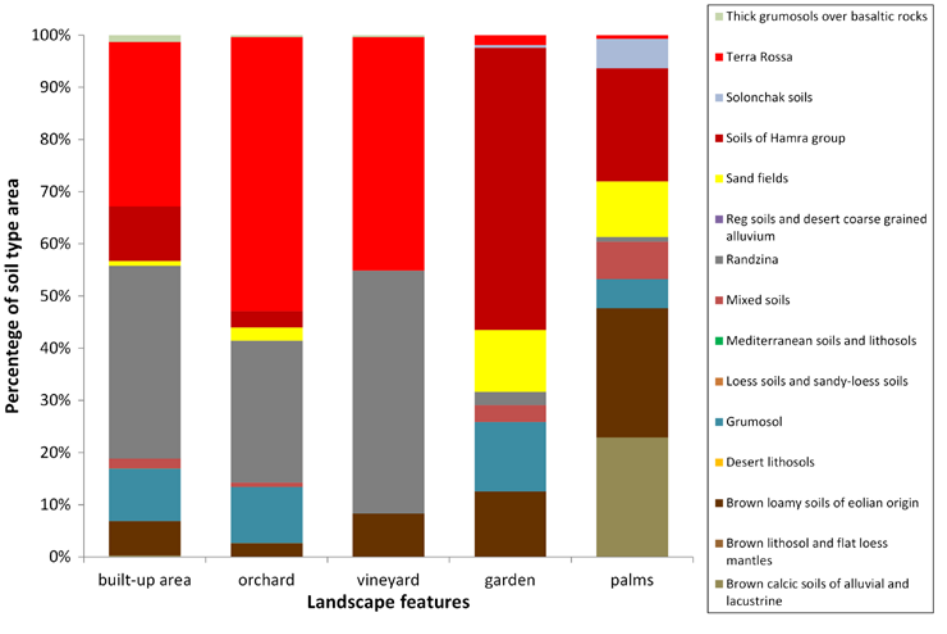

Figure 8A. Distribution of soil types within different human-made landscape features found in the study area. "Open space" landscape class was omitted from this figure.

3.3.2. Soil types

The human-dominated landscape classes as well as the ones of the Mediterranean vegetation and forests were mostly found on three types of soil: Terra Rossa and Rendzina soils (common in the mountains of Palestine) and Hamra Soil (a mature, non-calcareous red Mediterranean soil of sandy clay loam, common in the coastal areas of Palestine) (Figures 8A and 8B, Table S4).

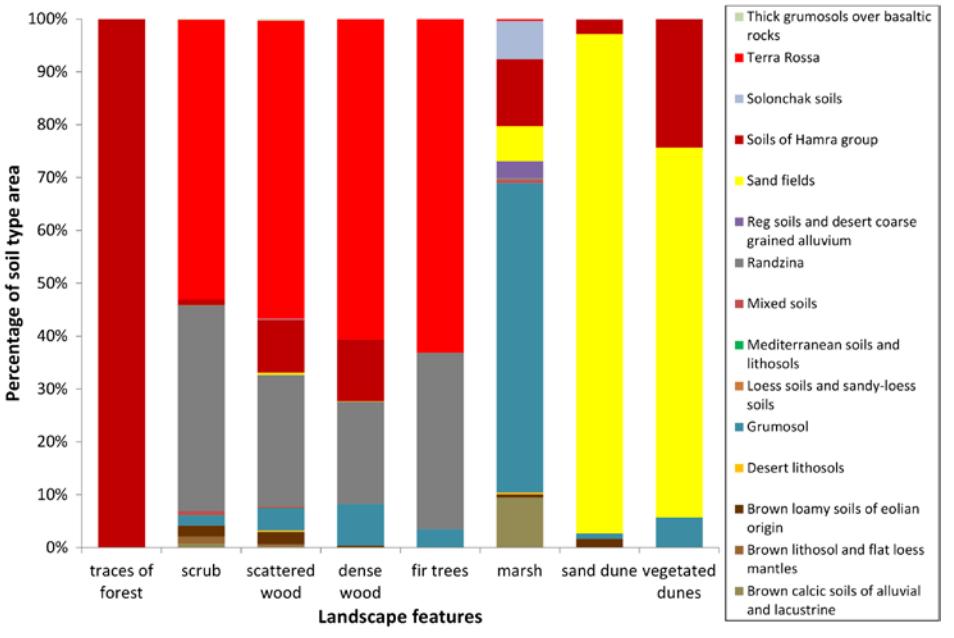

Figure 8B. Distribution of soil types within different natural landscape features found in the study area. "Open space" landscape class was omitted from this figure.

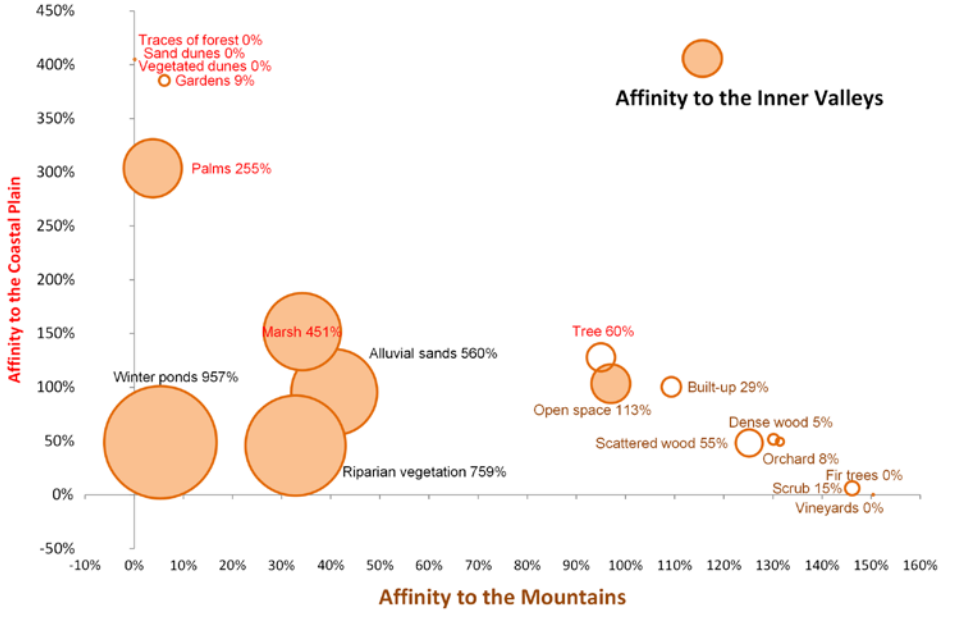

Figure 9. Affinity of the different landscape features to the major topographic regions: Mountains (*x*-axis), Coastal Plain (*y*-axis), Inner Valleys (bubble size). Affinity values above 100% indicate the tendency of a certain land cover/land-use class to a certain topographic region.

3.3.3. Topography

The most dominant landscape class was "open space," covering 88.3% of the Inner Valleys region, 80.5% of the Coastal Plain region and 75.5% of the Mountain region (Table S6). Natural vegetation classes were more common in the Mountain region (affinity >100%), except for the class "traces of forest" which

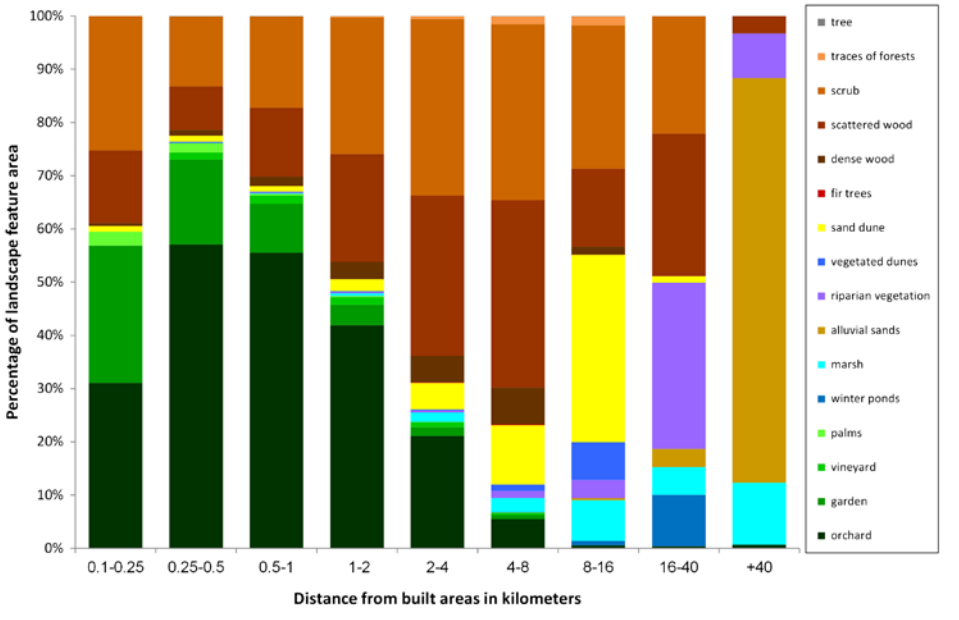

Figure 10. Figure representing the statistical analysis results regarding the percentage of area of all landscape features found on the PEF map with respect to their distance from built-up areas. "Open space" landscape class was omitted from this figure.

was entirely located within the Coastal Plain (Figure 9). The Mountain region was also where built-up areas, vineyards and orchards were concentrated. Landscape features that were entirely located in the Coastal Plain naturally included the coastal dunes, marshes and winter ponds commonly found in the Coastal Plain and Inner Valleys, respectively (Figure 9).

3.3.4. Distance from built-up areas

Most of the agricultural land-use types (green-shaded colours) were found within a distance of up to 2 km from built-up areas, and almost none were located beyond 8 km from built-up areas (Figure 10, Table S5). Natural land cover features were dominant in the landscape at distances greater than 2 km from built-up areas (Figure 10, Table S5).

4. Discussion

4.1. Completeness of information represented on the PEF map

Although approximately 40 years separate the PEF map and the WWI aerial photos, we found that almost all of the classes represented on the PEF map were also found on the aerial photos, as seen in the results (Table 1). Moreover, using a set of randomly chosen points, more than half of the landscape classes found on the PEF map remained the same on the aerial photos, and only 15% of the mismatches could be attributed to geo-referencing or to mapping errors (Table 1). The four landscape features with the highest change between the PEF map and the aerial photos were decrease in "wood" and "wetland" and an increase in "open space" and "agri-orchard" (Table S2). These differences can be mostly attributed to landscape changes that occurred between the 1870s and 1917/8, and which are related to human activities, mostly to the increase in human population and the foundation of new settlements. As was mentioned earlier, a slow process of development had taken place from the 1860s onwards (Naveh, 1981; Reifenberg, 1950). At the end of the nineteenth century and into the start of the twentieth century, wetlands were considered wastelands and great efforts were invested to drain the large wetlands (Kark & Levin, 2012). For this reason, some of the wetlands were drained, partly to increase the land for

Figure 11. This is part of the PEF map representing the area of Abu Kishk. In this area, we can notice that on the northern part we have what seems to be "scattered wood," but on the southern part, closer to the village of "el Jelil," we have what seems to be tree trunks that were cupped off, symbolising a wooded area that was cut down.

agriculture, to combat malaria, and partly as a consequence of urban development (Levin et al., 2009). This can explain the decrease in the number and area of wetlands, between the PEF map and the WWI aerial photo. With regard to the decrease in "wood" areas, this could be attributed to the expansion of agricultural land into wooded area, clearance of wood during WWI, woods used by locals for heating and cooking material, and for industry purposes, especially the charcoal industry (Karschon, 1982; Paz, 1980;

Thirgood, 1981). In most of the areas where a decrease in wetland and woodland was found between the PEF and WWI, open space and agricultural land took over. The changing landscape can even be seen on the PEF map, where wood clearances are clearly shown with symbols of tree stumps (Figure 11).

With respect to the results of the Kappa index, there are two main reasons for the low match between the PEF and the aerial photos in these 14 sites: land cover changes related to population growth and development of agricultural areas, and mapping errors. Geo-referencing errors in each of the historical sources used lead to errors when analysing the spatial correspondence between land cover maps (Pontius, 2000). The higher was the Kappa index, the lower was the AbsSumDiff index (Figure S4). Indeed, the random points examination results only strengthen this argument. In some of the sites where changes in land use were found, there was an increase in population, such as in Jerusalem (from 18 000 in 1868 to 62 578 in 1922), Jericho (from 300 in 1881 to 1919 in 1922) and Nazareth (from 4950 in 1868 to 7424 in 1922) (Table 1). In conclusion, many of the differences in land cover/land-use patterns between the PEF map and the WWI aerial photos could be related to historical processes (Table 1, Table S2), and we conclude that since in only 15% of the random points a mismatch was found due to mapping errors, the information shown on the PEF map is sufficiently reliable to represent the landscape of nineteenth century Palestine and to spatially analyse it.

4.2. Landscape reconstruction of nineteenth century Palestine

The open space class, covering almost 78% of the total research area, was probably not devoid of vegetation and human use (Conder et al., 1881; Kark, 1983). For example, the surroundings of Jerusalem and Jericho were described as "very bare, but there is corn-land in the low ground" (Conder et al., 1881, Vol. Judea, p. 2). In other locations, there are descriptions of different dry land farming. Moreover, part of the "open space" was used as grazing land, for example, "the country south of Wady Simsim is scarcely cultivated at all, being all pasture land" (Conder et al., 1881, Vol. Judea, p. 263). The Mediterranean region is known for its herbaceous flora (Shmida, 1981); during the dry season, many of the shrubs (e.g., *Sarcopoterium Spinosum*) are in a semi-dormant phase, and therefore, parts of the land may appear bare. Nonetheless, in winter and spring annual plants emerge, forming suitable grazing land (also used by Bedouins) and enabling rain-dependent crops to be cultivated (shown in Figure 11 of Levin & Heimowitz, 2012). As the population of the late nineteenth century Palestine totalled approximately 450 000 (compared with 10 million today), and because cutting and grazing pressures were much stronger (Kark & Levin, 2012), large portions of the landscape were devoid of agricultural plantations and dense Mediterranean maquis, and were therefore depicted as open space. This also corresponds with the common practice of depicting vegetation on topographic maps: whereas woodlands and marsh lands are almost always mapped, heath (open, low-growing woody vegetation) and grassland are usually not shown on topographic maps at map scales smaller than 1:25 000 (Collier, Pearson, & Forrest, 1998).

Disregarding the open space areas, the biggest landscape feature was scrub with 6.5%. Scrub on the PEF map is "presumably a well-developed Batha … and different stages of degradation of a Maquis, especially *Quercetum calliprini*" (Eig, 1933, p. 244). Another description of scrub near Palmyra (present day Syria) was given in the PEF quarterly: "we passed through many scrubs of oak and styrax … we passed through scrubs of *Quercus coccifera, L.* and Pistacia palaestina, Boiss … but no forests" (Grover, 1893, p. 328). We conclude that scrub on the PEF map is a degraded maquis in different stages of degradation, or in other words, a garrigue area that was defined as an intermediate state between batha and maquis and characterised by dominant vegetation of bushes about 1 m in height and rich in shrubs. If indeed the scrub land represents a degraded wooded area, then we may conclude that the land once had a large wooded area (compare with Zohary, 1982). Summing the four categories of "dense wood," "scattered wood" and "scrub" together with "fir trees," a total of 13.5% of the total research area related to different stages of wood land. Secondly, we can learn from this analysis of the PEF map that landscape change processes were ongoing during the PEF survey, e.g., woodland clearances (Figure 11). These landscape changes were explained by Claude R. Conder, one of the main surveyors of the PEF map, as follows: "it is man, and not nature, who has ruined the good land" (Conder, 1878, p. 323).

There are many descriptions of nineteenth century Palestine made by different travellers often with different and even opposing views. For example, Mark Twain, an American writer, wrote about his journey to Palestine, in which he describes the landscape north of Safed as "desolate country whose soil was rich enough, but is given over wholly to weeds" and on his road to Jerusalem he notes that "there was hardly a tree or a shrub anywhere" (Twain, 1869, p. 361). Other travellers describe the land as green fertile and with many woods such as Yaacov Halevi Sapir, who describes in 1854 the forest of the area of Umm al-Fahm: "around are found large forests … some places in the forest, you can walk a few hours under the cover of the oak trees—in the darkness" (Paz, 1980, p. 49). The variation in the travellers' view point of the landscape is not surprising and can be found in the writings of travellers to Palestine as well as other regions of the world (Ben-Arieh, 1985; Whyte, 2002). The various view points of the landscape of Palestine in the nineteenth century depend on the season and year in which the travellers arrived in Palestine, the areas in which they travelled, their background and origin and other factors. With regard to the year and season, it is important to note that of the seven years in which the PEF survey was conducted (1871–1877), in two years, the annual rainfall was much higher than average (while the annual average rainfall in Jerusalem is 557 mm/year, in 1873, it was 1003 mm/year, and in 1877, it was 1090 mm/year); therefore, many wetlands and marshes were depicted by the PEF surveyors (Levin et al., 2009). Due to the fact that the travellers' literature describing a specific location may have been quite different and open to different interpretations, we adopted a quantitative method of digitally reconstructing the landscape. Indeed, historical maps and travellers records have been used in other studies to quantitatively reconstruct past landscapes (e.g., Fensham, 2008; Sanderson, 2009; Silcock, Piddocke, & Fensham, 2013).

Two landscape classes were drawn on the PEF map despite their small area. The first feature is "palms" that take up 0.03% of the total research area. It seems reasonable to believe that the PEF decided to mark palm trees because of their economic value and income made from the vending of their fruit. The second feature is "fir trees," which took only 0.02% of the total research area. It is reasonable to believe that the PEF "fir trees" were actually Aleppo pines (Liphschitz & Biger, 2001). The PEF map shows "fir trees" to be found only in three areas—Mount Carmel, a few sites in the Northern Galilee and other sites east of Jaffa in the Samaria mountain area (for a map see Figure S3). Although until the 1980s, it was accepted that "in the past Aleppo Pines covered vast areas of Israel-Palestine" (Liphschitz & Biger, 2001, p. 429), botanical, historical and geographical evidence showed that these trees were uncommon in Palestine's landscape in the past (Liphschitz & Biger, 2001).

During the digitization of the PEF map, we estimated the uncertainty in which we identified the attributes of landscape features as shown on the map. The landscape classes with the highest uncertainty were "scrub," "scattered wood" and "dense wood" with 7–15% high uncertainty (Table S1). Indeed, as was stated previously, much of the natural landscape classes of woody vegetation were at different stages of degradation (Perevolotsky & Seligman, 1998). Nature is in constant flux, building and degrading and rebuilding, and therefore, the surveyor's task of depicting the landscape was challenging. This challenge leads to ambiguity regarding the identification of landscape features during the process of the digitization (Fisher, 1999).

4.3. Spatial patterns in the land cover/land use of nineteenth century Palestine

As hypothesised, the spatial distribution of landscape features was governed by both physical and human factors. During the nineteenth century, when sand dunes and wetlands were common along the Coastal Plain and Inner Valleys, most towns and villages and their adjacent orchards and vineyards were located in the mountain areas. This division between the coastal and mountain areas has been a common characteristic of Palestine throughout its history (Karmon, 1956).

The Ottoman land code of 1858 defined land at a distance from a village where a human voice cannot be heard (a mile and a half away from the village, about 2.4 km) as "mawat" ("dead land"); in other words, unclaimed land where most of the grazing took place (Shehadeh, 1982). This corresponds to our findings that at distances of more than 2 km, natural vegetation classes were more common

than agricultural ones. Additionally, while examining the two other attributes, soil types and average annual rainfall, we found that an area with fertile soil and a decent amount of rainfall, usually more than 400 mm/year, would naturally be more attractive to human settlement. Additional factors influencing the spatial distribution of human settlements in Palestine included security considerations (favouring elevated locations), proximity to springs and others (Amiran, 1953).

5. Conclusions

This research demonstrated how to assess the thematic completeness of a historical map using aerial photos and that land cover/land-use features digitised from historical maps can be analysed quantitatively to uncover their relationships with physical and human factors. We showed that the PEF map is indeed a reliable historical geographic source that can be used for the purpose of depicting the nineteenth century landscape of Palestine. The digitization of the PEF map allowed us to explore new angles that were not previously explored and to add new quantitative information on the landscape of nineteenth century Palestine. This research created a database that contains a digital restoration of the nineteenth century landscape based on the PEF map, which can be used in future research on landscape changes and as a framework for other historical geography research. Moreover, this research can be used by ecologists to understand landscape changes, with implications for prioritising conservation actions, and in certain cases, even restoring past landscapes (as in the case of the Hula Lake, in the north of Israel; Hambright & Zohary, 1998). The PEF map provides us with a rare view of the past landscape, as seen by the cartographers of that time using powerful GIS tools and methods. By reconstructing the nineteenth century landscape of Palestine, we also hope that it will encourage more people to explore these valuable historical maps, not only of this region, but in other countries as well.

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