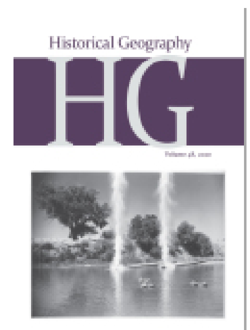
The Driving Forces Inducing Land Cover Changes in Israel's Northern Sharon Plain from the End of the Nineteenth Century to the Present Time

Gad Schaffer



Historical Geography, Volume 48, 2020, pp. 102-132 (Article)

Published by University of Nebraska Press
DOI: https://doi.org/10.1353/hgo.2020.0003

THE DRIVING FORCES INDUCING LAND COVER CHANGES IN ISRAEL'S NORTHERN SHARON PLAIN FROM THE END OF THE NINETEENTH CENTURY TO THE PRESENT TIME

GAD SCHAFFER,
TEL-HAI ACADEMIC COLLEGE

ABSTRACT: This research focuses on Israel's northern Sharon region, an area that underwent radical land cover changes. It examines the driving forces behind the changes in the northern Sharon Plain over four time periods: 1881, 1917, 1954–58, and 2011. To do this, historical land cover was reconstructed using different cartographical sources. The results show that the Sharon Plain has changed from mostly natural land cover features to mostly human-made ones. Some land cover categories have disappeared altogether (marshes, barren sand dunes). Each period examined had different proximate drivers that caused the land cover change. Moreover, at first, the main underlying causes of the change were mainly cultural, but in later periods these became more political and economic. This study demonstrates the importance of using historical map sources and the driving forces approach for understanding land cover changes over time.

KEYWORDS: *land use/land cover (LULC) changes, historical maps, GIS, driving forces, Sharon Plain, Israel*

INTRODUCTION

In recent decades there have been many studies worldwide on landscapes and land use/land cover (LULC) changes.[1] The reasons for the increase in research on these topics are related to two main factors. The first is a growing awareness of the link between LULC changes and environmental change.[2] Research on LULC changes contributes to the maintenance of a balanced ecosystem and helps humanity more efficiently face present-day challenges such as floods, droughts, food shortages, and climate change.[3] The second is the advancements made in geospatial technology since 1990, which make the quantitative analysis of LULC changes more accurate, easier, and faster.[4]

Gaining new insights into LULC changes and the reasons behind them often requires mapping and comparing the results to other sources from the past. To map LULC changes over time, most researchers use sources such as historical and present-day maps, aerial photographs, and satellite imagery, processed within geographic information system (GIS) software programs. Historical cartographic sources contain valuable information about the past, and in recent years there has been a rise in the use of these sources in research.[5] Nonetheless, errors can be found in these, as well as new errors that form in the process of using them with GIS software programs, and therefore a critical eye is needed when examining them.[6]

Different perspectives and approaches attempt to further understand the causes behind these changes, each with their own strengths and weaknesses.[7] One useful and encompassing approach is the driving forces approach, which began as an environmental intervention policy framework but was later adopted by different LULC researchers.[8] The driving forces approach aims to understand the causes, processes, and outcomes by dividing the causes into several driving forces across different levels.[9] The proximate driving forces are the immediate local forces that have caused the changes. Below this level are the underlying driving forces, which are usually divided into five main types: socioeconomic, political, technological, natural, and cultural forces, and which can be examined at the local, regional, national, or global scales.[10]

This research examines the driving forces behind LULC changes in the northern Sharon Plain between 1881 and 2011. The Sharon Plain is a region that has undergone the most radical land cover changes in Israel.[11] The Sharon region is a flat plain of approximately 700 km^2 stretching from the Yarkon River in the south to the Taninim River in the north, and from the Mediterranean Sea in the west to the Samaria Mountains in the east (see fig. 1). Until the nineteenth century, most of the Sharon region was composed of natural features. Large land cover changes in the area began at the end of the nineteenth century. Fortunately, during that time, a growing interest in Palestine had developed, which resulted in many cartographical sources.[12] Today, the Sharon region is one of the most populated regions in Israel, consisting of 101 settlements with

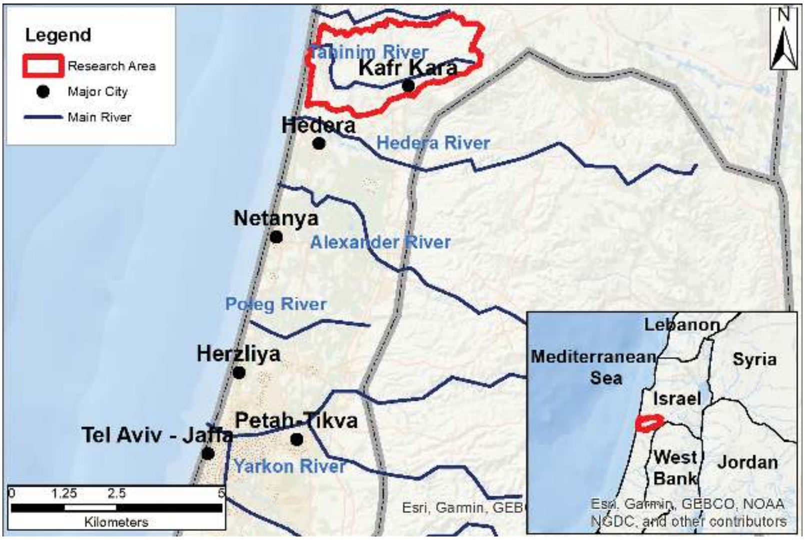


FIG. 1. The Sharon Plain. The researched area is circled in red.

a population of 1,208,900.[13] All this despite its existing environmental conditions such as marsh areas and floods, which make it a less than ideal place to live.

Today the region suffers from annual winter floods,[14] and it is likely that these could intensify due to climate change.[15] Current predictions for the Middle East signal prolonged periods of drought mixed with heavy precipitation for short periods of time.[16] Indeed, there are already signs of these changes happening in Israel.[17] Moreover, at present several projects aim to bring back some past landscapes, for example, by replanting oak trees.[18] This gives rise to an interesting question: will the projects improve or deteriorate the ecosystem in the region? This study hypothesizes that some present-day environmental challenges in the Sharon Plain—mostly seasonal floods—could be better understood by examining past LULC changes Although this is a local case study, the combination of historical-geographical sources and a driving forces analysis approach can provide a better understanding of LULC changes in this area, and identify the similarities and differences compared with other areas around the world.

MATERIALS AND METHODS

Research Area

The research area chosen is the Ada-Taninim watershed located in the northern part of the Sharon region (see fig. 1). This area covers approximately 279 km^2, includes eighteen settlements (as of 2019), and still has a larger mixture of LULC categories than other more southern watersheds in the Sharon Plain. Historically, the Sharon Plain can be divided into three distinct areas. For centuries, the area that borders the Mediterranean Sea was mostly covered by sandstone ridges and sand dunes.[19] The middle region was once predominantly marshlands and forests, and the third region, which borders the Samaria Mountains, primarily consisted of oak and carob forests.[20]

Research Time Frame and Sources

The research examines the land cover changes during four different time periods: 1881, 1917, 1954–58, and 2011. A digital elevation model with a horizontal grid spacing of 30 arc seconds was used to define the Ada-Taninim watershed, as well as a map of the Ada-Taninim drainage area.[21] The first cartographical source used to reconstruct the late nineteenth century was a map by the British Palestine Exploration Fund (PEF) at a scale of 1:63:360 (see table 1 for all map references).[22] The PEF survey was done between 1871 and 1877 and published in 1881. The map is accompanied by three memoirs.[23] The map provides a rare view of the research area before the construction of major settlements and the development of Palestine. The PEF map is considered the first accurate map of Palestine.[24] The second cartographical source used to reconstruct the early twentieth century was the Caesarea map sheet, which is part of a larger 1917 map of Palestine.[25] This map is a reprint of the PEF map with added details. The 1917 map was updated by British Corps for war purposes and is also highly accurate. Since there are no complete maps of the area made in any one particular year in the mid-twentieth century, eight different maps made between 1954 and 1958 were used. To reconstruct the present-day land cover, both satellite imagery from 2011 in a resolution of 0.5 meters and a 2014 map were used.[26] While present maps of the area are available, they all have a downside. The Israeli updated present-day maps at a scale of 1:25,000 did not cover the entire area—one area was still in preparation by the Survey of Israel. Furthermore, both updated present-day Israeli maps, at a scale of 1:25,000 and 1:50,000, were done using an orthophoto, and thus some of the land cover classes were unclear and their borders hard to define. For example, the borders of agricultural fields and of built-up and forest areas were much clearer in the satellite imagery than on the map, while other categories, such as water bodies, were much clearer and defined on the maps. Due to these limitations, this research used the satellite imagery from 2011 to digitize the land cover and the 2014 map to verify that the digitization was done correctly and to categorize the land cover accordingly and with accuracy.

Land Cover Reconstruction

The first step to reconstructing the land cover was to georeference the sources. The 1881 PEF map, as well as the 2011 satellite imagery, were already georeferenced.[27] The 1917 map, the 1954–58 maps, and the 2014 map were georeferenced using the four corners of the map, formed by the longitude and latitude lines. The second step was to determine the categorization of the land cover. This was done using a similar method to earlier published research.[28] For this study, seven broad categories were chosen because they represent the drawn features on all the sources: cultivated land, built-up areas, forests, Batha shrublands, barren sparse dunes and ridges, marshes, and water bodies (table 2). Moreover, water streams and rivers were also digitized. The third step was to digitize the land cover across all sources. This was accomplished using ArcGIS software (version 10.5.1) on a scale of 1:20,000. To compare the different digitized layers to each other during the fourth step, quantitative data was extracted from each layer using the summarize tool. Area sizes of land cover categories were extracted, and the dynamic percentage of change was calculated for each period. Moreover, the tabulate area tool was used to examine the transformation of the land cover categories between 1881 and 1917, 1917 to 1954–58, and 1954–58 to 2011.

Driving Forces Approach

The research uses the driving forces approach to understand the background of the land cover changes. Analysis focuses mainly on the primary driving forces that directly affected the changes in the research

Table 1. The cartographical sources used for reconstructing the land cover.

Mapping Agency	*Type of Source*	*Name of Source*	*Publish Year*	*Source Scale*
Palestine Exploration Fund	Map	Sheet 7, 8, 9, 10 [a]	1881	1:63,360
British War Office	Map	Caesarea sheet 7 and 8 [b]	1917	1:63,360
Survey of Israel	Map	Ma'anit sheet 15–20 [c]	1954	1:20,000
Survey of Israel	Map	Daliya sheet 15–22 [d]	1955	1:20,000
Survey of Israel	Map	Caesarea sheet 14–21 [e]	1956	1:20,000
Survey of Israel	Map	Hedera sheet 14–22 [f]	1956	1:20,000
Survey of Israel	Map	Regavim sheet 15–21 [g]	1958	1:20,000
Survey of Israel	Map	Ijzim sheet 14–22 [h]	1958	1:20,000
Survey of Israel	Map	Mishmar Haemek sheet 16–22 [i]	1958	1:20,000
Survey of Israel	Map	Umm El Fahem sheet 16–21 [j]	1958	1:20,000
Survey of Israel	Map	Yokneam [k]	2014	1:50,000
ESRI, DigitalGlobe	Satellite imagery	WV02 resolution 0.5 [l]	2011	

[a] C. R. Conder and H. Kitchener, *Palestine Exploration Fund—Survey of Western Palestine 1:63,000 Map* (London: Palestine Exploration Fund, 1881).

[b] War Office, *Palestine, Sheet 7 and 8 Caesarea, Map at a Scale of 1:63,360* (1917).

[c] Survey of Israel, *Ma'anit Sheet 15–20, Map at a Scale of 1:20,000* (1954).

[d] Survey of Israel, *Daliya Sheet 15–22, Map at a Scale of 1:20,000* (1955).

[e] Survey of Israel, *Caesarea Sheet 14–21, Map at a Scale of 1:20,000* (1956).

[f] Survey of Israel, *Hedera Sheet 14–22, Map at a Scale of 1:20,000* (1956).

[g] Survey of Israel, *Regavim Sheet 15–21, Map at a Scale of 1:20,000* (1958).

[h] Survey of Israel, *Ijzim Sheet 14–22, Map at a Scale of 1:20,000* (1958).

[i] Survey of Israel, *Mishmar Haemek Sheet 16–22, Map at a Scale of 1:20,000* (1958).

[j] Survey of Israel, *Umm El Fahem Sheet 16–21, Map at a Scale of 1:20,000* (1958).

[k] Survey of Israel, *Yokneam Sheet, Map at a Scale of 1:50,000* (2014).

[l] ESRI, DigitalGlobe, *World Imagery [Basemap], Resolution 0.5 Meters* (Redlands, CA: ESRI, 2011).

area. The driving forces were analyzed qualitatively. However, the importance value of every driving force compared to other driving forces was not measured. Proximate and underlying driving forces were examined for each land cover category that changed between the periods examined.

Table 2. Land cover classes used in this research.

Land Cover Categories	*Details of Land Cover Categories*
Cultivated Land	An area of orchards, agricultural fields (irrigated and non-irrigated), and large vegetable gardens (a category found on the PEF map).
Batha Shrublands	Areas of vegetation cover that include various annual herbaceous flora (during the dry seasons, many of the herbaceous plants are in a semi-dormant phase and part of the land may appear bare, while in the winter and spring annual plants emerge, forming a low vegetation cover of the land) and vegetated sand dunes.
Barren Sparse Dunes and Ridges	Limestone ridges and sand dune areas with no to minimal vegetation cover.
Built-up Areas	Areas of human settlement, such as villages, towns, and cities, mostly comprising built-up areas with minimal vegetation cover, including large highways.
Forests	Areas of highly natural vegetation cover, which includes natural Mediterranean forests and planted forests.
Marshes	Areas where the water covers the ground for long periods of time, partly covered by water-adapted herbaceous plants.
Water Bodies	Larger winter ponds or artificial areas of water.

RESULTS

Land Cover Reconstruction

According to the 1881 map, the largest category of land cover area in the study was Batha shrublands (54.83 percent), followed by forests (36.98 percent), while the smallest land cover category was built-up areas (0.15 percent) (see table 3, figure 2). In 1917 the largest type of land cover area was still Batha shrublands (60.36 percent) and forests (32.86 percent), while the smallest land cover area was still built-up areas (0.15 percent) (see table 3, figure 3). According to the 1954–58 maps, the largest type of land cover area was Batha shrublands (76.82 percent), followed by—with a large margin—forests (7.66 percent) and cultivated land (7.01 percent), and the smallest land cover was water bodies (0.51 percent) (see table 3, figure 4). Finally, according to the 2011 source, the largest land cover category in the study area was cultivated land (37.70 percent), followed by Batha shrublands (28.91 percent) and built-up areas (16.37 percent), while the smallest category was water bodies (1.14 percent) (see table 3, figure 5).

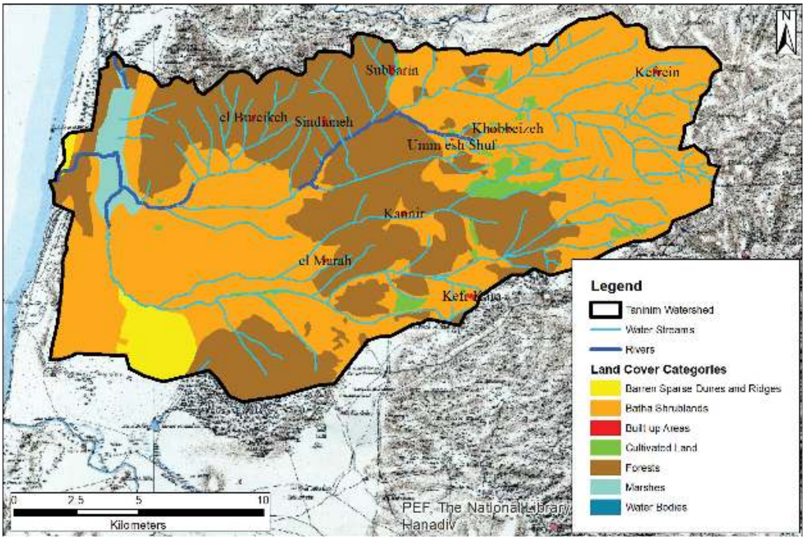


FIG. 2. The digitized land cover map as depicted on the 1881 PEF map.

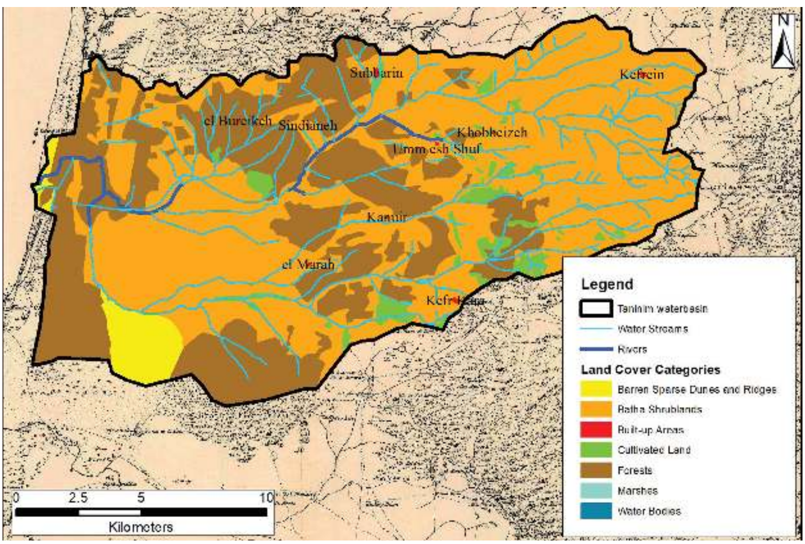


FIG. 3. The digitized land cover map as depicted on the 1917 map.

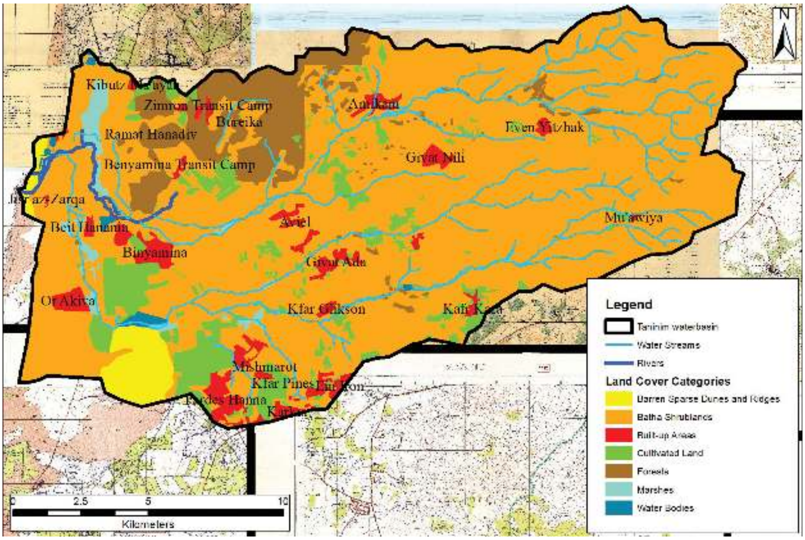


FIG. 4. The digitized land cover map as depicted on the 1954–58 maps.

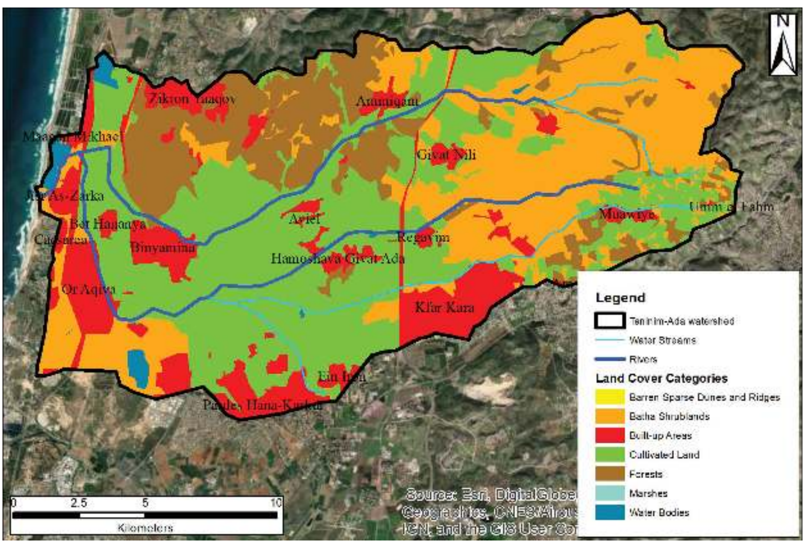


FIG. 5. The digitized land cover map as depicted on the 2011 satellite imagery.

Table 3. Land cover changes for each period examined. The total area in square kilometers and percentage of the total research area is provided for each land cover category. The magnitude of land cover changes in percentage for each category was calculated between 1881 and 1917, 1917 to 1954–58, and 1954–58 to 2011.

	1881		*1881–1917*	*1917*		*1917 to 1954–58*	*1954–58*		*1954–58 to 2011*	*2011*	
Land Cover Categories	*Area in km²*	*% of Total Area*	*Magnitude of change in %*	*Area in km²*	*% of Total Area*	*Magnitude of change in %*	*Area in km²*	*% of Total Area*	*Magnitude of change in %*	*Area i n km²*	*% of Total Area*
Cultivated Land	7.68	2.76	22.11	9.37	3.38	107.68	19.47	7.01	442.59	105.64	37.70
Barren Sparse Dunes and Ridges	8.37	3.00	8.03	9.04	3.25	-19.52	7.27	2.62	-100.00	-	-
Batha Shrublands	152.75	54.83	9.70	167.57	60.36	27.39	213.47	76.82	-62.05	81.01	28.91
Built-up Areas	0.41	0.15	2.73	0.42	0.15	2430.62	10.72	3.86	327.91	45.86	16.37
Forests	103.02	36.98	-11.44	91.23	32.86	-76.68	21.28	7.66	109.02	44.48	15.87
Marshes	6.36	2.28	-100	—	—	-	4.24	1.53	-100.00	-	-
Water Bodies	-	-	-	—	—	-	1.43	0.51	123.69	3.20	1.14
Total Area	279	100		278	100		278	100		280	100

Magnitude of Land Cover Change

According to magnitude of change calculations, between 1881 and 1917 cultivated land had the highest increase (22.1 percent), although the size of this category was still very small, just 3.38 percent of the total research area (see table 3). The greatest decrease (100 percent) was found in marshes, of which 78.08 percent became forests and 21.92 percent became Batha shrublands by 1917 (see tables 3 and 4). Another decrease of 11.44 percent was seen in forests (see table 3). While some new forest areas were planted between 1881 and 1917 in Batha shrublands (13.48 km^2) and marshes (4.96 km^2), many more were cleared and became Batha shrublands (27.39 km^2) by 1917 (see table 4). Regarding the magnitude of change between 1917 and 1954–58, built-up areas had an increase of 2,430.63 percent, while remaining one of the smallest in area size (only 3.86 percent of the total area between 1954 and 1958) (see tables 3 and 4). The biggest decrease in this period was in forests (76.68 percent). Most 1917 forest areas were cleared out by 1954–58 and became Batha shrublands (62.89 km^2) and cultivated land (6.78 km^2) (see table 4). Lastly, according to the magnitude of change calculations, between 1954–58 and 2011, the highest increase was in cultivated land (442.59 percent), followed by built-up areas (327.91 percent), while the biggest decrease was in marshes (100 percent) and barren and sparse dunes and ridges (100 percent) (see table 3).

Table 4 shows that the increase in cultivated land and built-up areas seen in 2011 came at the expense of all land cover category types found there between 1954 and 1958. There are two land cover categories that completely disappeared in the 2011 source: barren and sparse dunes and ridges, and marshes. Marsh areas that existed in 1954–58 disappeared completely and became mostly cultivated land (72.70 percent), Batha shrublands (13.73 percent), and built-up areas (10.11 percent) by 2011. What was barren and sparse dunes and ridges in 1954–58 became Batha shrublands (51.01 percent), built-up areas (25.56 percent), and water bodies (22.49 percent) by 2011 (see table 4). Moreover, it seems large water bodies were not depicted in the 1881 and 1917 maps but only started to appear in the 1954–58 and 2011 maps.

Table 4. The transformation of land cover categories between 1881 and 1917, 1917 to 1954–58, and 1954–58 to 2011 (amount of change in square kilometers and the dynamic of land cover change in percentage).

	1881—1917		*1917—1954–58*		*1954–58—2011*	
Changes in Land Cover Categories	*km^2*	*Dynamics of change in %*	*km^2*	*Dynamics of change in %*	*km^2*	*Dynamics of change in %*
Cultivated Land to Barren Sparse Dunes and Ridges	0.00	0.00	0.00	0.00	0.00	0.00
Cultivated Land to Batha Shrublands	2.00	86.84	8.57	94.48	1.00	14.17
Cultivated Land to Built-up Areas	0.00	0.00	0.00	0.00	5.15	73.29
Cultivated Land to Forests	0.30	13.16	0.43	4.73	0.87	12.42
Cultivated Land to Marshes	0.00	0.00	0.07	0.78	0.00	0.00
Cultivated Land to Water Bodies	0.00	0.00	0.00	0.00	0.01	0.13
Barren Sparse Dunes and Ridges to Cultivated Land	0.00	0.00	0.87	43.45	0.03	0.35
Barren Sparse Dunes and Ridges to Batha Shrublands	0.00	1.23	0.93	46.35	3.75	51.61
Barren Sparse Dunes and Ridges to Built-up Areas	0.00	0.00	0.00	0.06	1.86	25.56
Barren Sparse Dunes and Ridges to Forests	0.39	98.77	0.00	0.00	0.00	0.00
Barren Sparse Dunes and Ridges to Marshes	0.00	0.00	0.10	5.15	0.00	0.00
Barren Sparse Dunes and Ridges to Water Bodies	0.00	0.00	0.10	4.99	1.63	22.49
Batha Shrublands to Cultivated Land	0.86	5.73	10.64	40.83	85.11	60.77
Batha Shrublands to Barren Sparse Dunes and Ridges	0.59	3.93	0.04	0.17	0.00	0.00
Batha Shrublands to Built-up Areas	0.00	0.00	4.57	17.56	26.74	19.09
Batha Shrublands to Forests	13.48	90.34	7.40	28.43	27.28	19.47

Table 4. Continued

Changes in Land Cover Categories	*1881—1917*		*1917—1954–58*		*1954–58—2011*	
	km²	*Dynamics of change in %*	*km²*	*Dynamics of change in %*	*km²*	*Dynamics of change in %*
Batha Shrublands to Water Bodies	0.00	0.00	0.73	2.81	0.94	0.67
Built-up Areas to Cultivated Land	0.01	11.33	0.08	22.61	0.94	77.59
Built-up Areas to Batha Shrublands	0.05	88.67	0.27	77.39	0.01	0.96
Built-up Areas to Barren Sparse Dunes and Ridges	0.00	0.00	0.00	0.00	0.00	0.00
Built-up Areas to Forests	0.00	0.00	0.00	0.00	0.26	21.45
Built-up Areas to Marshes	0.00	0.00	0.00	0.00	0.00	0.00
Built-up Areas to Water Bodies	0.00	0.00	0.00	0.00	0.00	0.00
Forests to Cultivated Land	3.14	10.12	6.78	8.76	1.08	20.83
Forests to Batha Shrublands	27.39	88.33	62.89	81.28	2.02	39.16
Forests to Barren Sparse Dunes and Ridges	0.48	1.55	0.21	0.27	0.00	0.00
Forests to Built-up Areas	0.00	0.00	5.56	7.19	2.06	39.93
Forests to Marshes	0.00	0.00	1.36	1.75	0.00	0.00
Forests to Water Bodies	0.00	0.00	0.58	0.75	0.00	0.08
Marshes to Cultivated Land	0.00	0.00	0.00	0.00	3.04	72.70
Marshes to Batha Shrublands	1.39	21.92	0.00	0.00	0.57	13.73
Marshes to Barren Sparse Dunes and Ridges	0.00	0.00	0.00	0.00	0.00	0.00
Marshes to Built-up Areas	0.00	0.00	0.00	0.00	0.42	10.11

Table 4. Continued

Changes in Land Cover Categories	*1881—1917*		*1917—1954–58*		*1954–58—2011*	
	km^2	*Dynamics of change in %*	*km^2*	*Dynamics of change in %*	*km^2*	*Dynamics of change in %*
Marshes to Water Bodies	0.00	0.00	0.00	0.00	0.15	3.47
Water Bodies to Cultivated Land	0.00	0.00	0.00	0.00	0.73	75.45
Water Bodies to Batha Shrublands	0.00	0.00	0.00	0.00	0.10	9.98
Water Bodies to Barren Sparse Dunes and Ridges	0.00	0.00	0.00	0.00	0.00	0.00
Water Bodies to Built-up Areas	0.00	0.00	0.00	0.00	0.14	14.58
Water Bodies to Forests	0.00	0.00	0.00	0.00	0.00	0.00
Water Bodies to Marshes	0.00	0.00	0.00	0.00	0.00	0.00

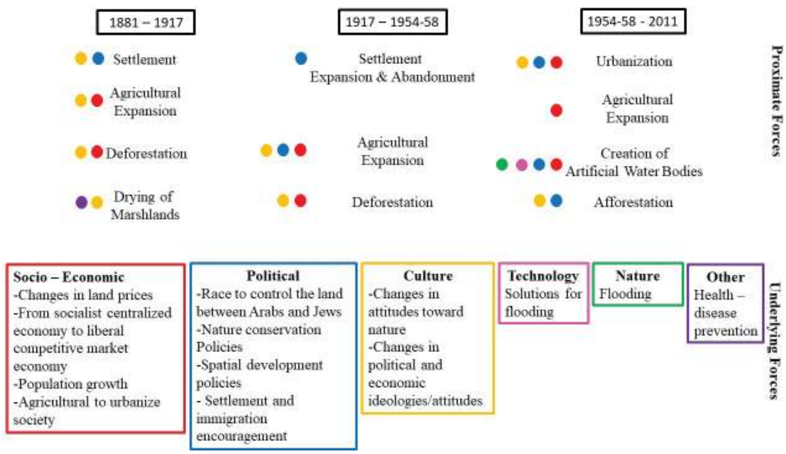


FIG. 6. The proximate and underlying driving forces that influenced the land cover changes in the research area. The proximate driving forces are divided into the three land cover periods: 1881 to 1917, 1917 to 1954–58, and 1954–58 to 2011. The underlying driving forces are framed in different colored squares. Next to each proximate driving force a colored dot represents an underlying driving force. Figure by author.

DISCUSSION

Historical Background

Throughout history, the Sharon Plain was settled by different people. These settlements were located primarily near a main water source (such as the Yarkon River) or on the coastal strip (for example, Jaffa and Caesarea).[29] During the seventeenth century, as the Ottoman Empire began to weaken, Palestine had also witnessed a slow and gradual process of political decline, which was caused by two main factors. The first was the undermining of the regime's foundations and order due to internal revolts and instability. The second was the general disinterest of changing rulers in this geographical area.[30] The gradual process of political decline resulted in a lack of security and development and the over-exploitation of natural resources, which then resulted in the abandonment of small settlements and a general decrease in population.[31] By the beginning of the nineteenth century, the Sharon Plain was one of the most deserted places in Palestine.[32] Different proximate and underlying driving forces have contributed to the land cover changes in the studied area since then (see figure 6).

Land Cover Changes—1881 to 1917

The first period of land cover changes in this research, from 1881 to 1917, covers the final years of the Ottoman Empire, which ruled the Sharon region for over five hundred years. This period ends in 1917, when the British took control of the territory. The four main proximate driving forces for land cover changes during this period were the development of new rural settlements, agricultural expansion, draining the marshes, and deforestation. These forces were the result of mainly cultural and economic underlying forces. The first part of this period symbolizes the beginning of the new Jewish settlement of Palestine, which started in 1882. Jewish settlements relied on agricultural produce to survive. During this period, study results show a slight increase in cultivated areas, but the largest change was the decrease in marshlands, followed by forest areas.

DRAINING THE MARSHES

To early Jewish settlers, the marshlands were a challenge. Historically the inner Sharon area was mostly marshlands and forests. Marshes were present in the Sharon Plain because of four physical factors. The first factor is that the inner Sharon area lies on clay soil, where the infiltration rate of water is slow.[33] Second, in the past, the entire area was covered in streams and rivers that flowed from the Samaria Mountains in the east, through the Sharon Plain, and into the Mediterranean Sea (see figure 2).[34] Third, the sandstone ridges and sand dunes in the west acted as a barrier that trapped mountain waters and rainfall in the area for long periods of time.[35] The fourth factor is the high level of groundwater in the region, which sometimes reaches a depth of just 6–20 meters.[36]

Early Jewish settlers' solution for the marshes was to drain them to a nearby river and plant eucalyptus trees in some of the dried-out areas.[37] These actions were carried out in each of the new Jewish settlements. For example, the first in the area was Hadera, founded in 1891 near the Hadera River (see figure 1).[38] As settlers would later note, "Hadera was, in those days, a place of marshes, created by sand barriers . . . which prevented the flow of water into the sea, and as a result, the area was an incubation place for the Anopheles mosquito. Indeed, the fever was the greatest enemy of the settlers. Many of them got ill and died."[39] In

1891 the first drainage channels were constructed to transfer the water from the marshlands to the Hadera River. Between 1892 and 1893, settlers also began to plant eucalyptus trees in the dried-out marsh. By 1896 some 4,000 dunam of Australian eucalyptus trees had been planted in the area.[40] Today this area, called the Hadera Forest, is the largest of its kind in Israel.[41] As time passed, the settlers realized that the most effective solution for drying out the marshlands was to drain them rather than plant trees.[42] These actions increased the flow of water from the marshlands into the rivers. Similar challenges and solutions that preoccupied early settlers can be seen in the other cases of settlement in the Sharon Plain.

Drying the marshes is linked to cultural attitudes. Historically, marshlands were seen as wastelands all over the globe, and as a result, they were drained and their waters diverted.[43] The reason behind this negative attitude was the fact that marshlands were a good habitat for the mosquitoes that spread malaria. In addition, marshlands were considered wasted fertile lands that should be drained and used for agriculture. The Hula Valley (in Israel) is another similar example of a large area of wetlands in the Galilee region that was first drained by the British during the Mandate period in Palestine and then completely dried up by the State of Israel. However, there is a fundamental difference between the two cases, and between them and other areas around the world. In the case of the Hula Valley, after draining, settlers discovered that the soil was not suitable for agriculture.[44] Moreover, drying the Hula Valley destroyed the way of life led by the Bedouin Awarna tribe, who lived on the banks of these marshlands. Furthermore, it caused environmental damage and soil erosion and resulted in fires in the summertime.[45] Contrary to the Hula case, the soil of the dried-up marshlands in the Sharon area was found to be fertile and good for agriculture. However, due to the land cover modifications made to reduce the marshlands, floods became an even greater annual challenge.[46]

It is important to note that in the 1917 map no marshland cover appears, while in the 1954–58 maps we once again find marshlands, which completely disappear in the 2011 source. There can be two explanations for the disappearance of all the original 1917 marshes. The first is that several years of drought disrupted all marshes, so when the area was mapped, there was no trace of them. Another possible explanation is a mapping error. However, the final disappearance of the marshes in 2011 is certain. Settlements, agricultural land, and artificial water bodies can be found on the map's former marshes.

DEFORESTATION

The origin of the name "Sharon" seems to derive from the Acadian name Sarnu, which means "forest."[47] In the Hellenistic period the region was named Drumos, which means "an oak forest" in Greek.[48] Ancient historical sources describe the Sharon forests as very wide and covering almost the entire Sharon region.[49] There is some evidence that the oak trees from this area were used as combustible materials for the glass factory in the Byzantine period (300–630 AD).[50] There is also proof that the Crusaders (1100–1291 AD) used the wood from the Sharon region for their iron industry.[51]

It is argued that until the Napoleonic period (around 1798–99) forests still covered a large portion of the Sharon Plain. Nonetheless, the real change first began in 1831, when Ibrahim Pasha conquered Palestine for a short time. Under Pasha's orders, the trees from forests in the southern part of the Sharon were used for ship construction.[52] Pictorial tree stump symbols (see figure 7) can be found on the 1881 map. During the First World War (1914–18), the Ottoman Empire continued to cut down trees to operate the Ottoman steam trains and for the war efforts. By the end of the war, only traces of forests could be found.[53] The Ottoman Empire's deforestation of the Sharon Plain was quite a common practice during that period. Indeed, in the eighteenth and nineteenth centuries, other parts of the world were also subjected to deforestation. Later, from the mid-nineteenth century on, attitudes changed, and afforestation slowly became the main practice.[54]

Land Cover Changes—1917 to 1954–1958

The second period of land cover change, from 1917 to 1954–58, involved political changes in the region. This period begins with the British occupation of Palestine. In 1948 the British Mandate ended, and the State of Israel was established. The three main proximate driving forces for land cover changes during this period were settlement changes (creation of new settlements, the expansion of existing settlements, abandonment

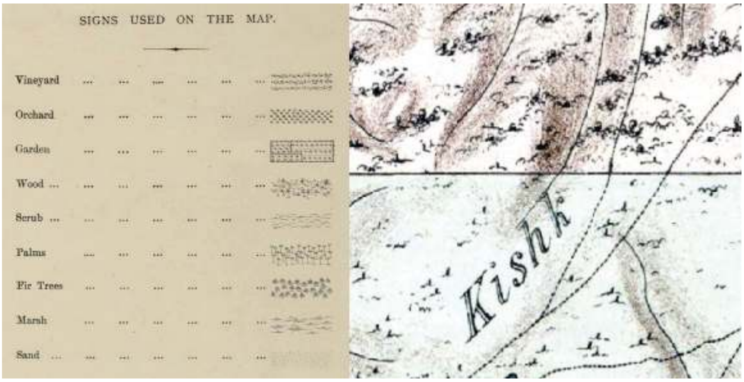


FIG. 7. The 1881 map legend (left), with the remains of a forest on the upper side and tree stumps at the bottom (right).

of settlements), agricultural expansion, and deforestation. The most important underlying driving force in this period was politics.

SETTLEMENT CHANGES

Throughout history, the Sharon Plain was settled by different people mostly near the main water sources and coastal area.[55] Remains have been found of past human settlements such as the Roman harbor city of Caesarea, built between 22 and 10 BC.[56] However, most settlements did not last long.[57] In 1881 there were only nine small villages in the research area consisting of just a few hundred people.[58] The absence of large, long-standing settlements in this region can be linked to security problems: the Sharon is a low and flat area, and therefore has a distinct geostrategic disadvantage.[59] Moreover, the Via Maris, the ancient road used from 3300 BC onward by various merchants and armies as a path across Africa, Asia, and Europe, was located between the Sharon marshlands in the west and the slopes of the Samaria Mountains in the east, and was another security disadvantage.[60] Lastly, the reason for the scarcity of human settlement in the inner part of the Sharon was the large amount of water, which acted as a hotbed for malaria and other related diseases.[61]

In the nineteenth century new powers entered Palestine and proceeded to acquire and develop land.[62] These events created new job opportunities and later attracted population, including Arabs from the neighboring areas of the empire and Jews from the Ottoman Empire and Europe.[63]

Between 1917 and 1954–58, the largest land cover change was the increase of built-up areas (see table 3). Under the British Mandate, population in the Sharon area increased and built-up areas consequently expanded.[64] In 1917 there were only nine settlements, but by 1954–58 there were twenty-two. However, a closer look at the data in table 4 also reveals other trends. While an increase of 3.71 percent in built-up areas occurred because of settlement creation and expansion, table 4 shows that in 1954–58, 10.13 km^2 of 1917 built-up areas became forests and Batha shrublands. The explanation for the abandonment of settlements is related to the first Arab-Israeli War of 1948. As a result of this war, eight Arab villages in the research area were abandoned.[65] Some of these settlements later became new Jewish settlements, such as Givat Ada, which is partly located in the former Arab settlement El Marah. Other abandoned settlements appear on the maps as tree-covered areas or Batha shrublands, such as Subbarin and Sindianeh. From an examination of the maps, it seems that these abandoned villages were drawn on the 1954–58 maps with the land cover that surrounded the area. While the maps do show abandoned buildings, they appear hollow and surrounded by natural features, unlike settled areas that were depicted as black squares.

Changes in land cover following an influx of human settlement are not new. What differentiates one case from another is the reason for the new settlement. Possible reasons include the search for food and water, the search for a safe area, and politics. In the case of the Sharon Plain, the reason for the new Jewish settlement was the ideological reason of Zionism. The primary aim of Zionist ideology was to strive for national salvation for the Jewish people by establishing a Jewish state. This ideology encouraged Jews from around the world to immigrate to Palestine and settle there.[66] Zionist immigration started in 1882.[67]

Land Cover Changes—1954–1958 to 2011

The third and last period of land cover changes is between 1954–58 and 2011. At the beginning of this period, Israel was still a young developing country, with an economy based on agricultural exports. By the end of this research period, Israel had become a highly urbanized, developed country, and its main exports became services and technologies. Moreover, Israel has opened to globalized economy and trends. The four main proximate driving forces for land cover changes during this period were urbanization, agricultural expansion, afforestation, and creation of artificial water bodies. The three important underlying driving forces during this period are economic, political, and cultural, with natural forces also a factor but to a smaller degree.

URBANIZATION

Despite the increase in population since 1881, the most drastic changes occurred from the 1950s onward. The growth in population is linked to the national trends of that period. With the establishment of the State of Israel in 1948, waves of Jewish immigration began to occur. First came Jewish European immigrants that survived the Holocaust, and later Jews who fled Arab countries due to deteriorating relations between these countries and Israel.[68] Since at that time Israel was still a country whose main export was agriculture, many settled in agricultural areas like the Sharon. The proximity to Tel Aviv and its larger job opportunities was yet another reason to settle in the Sharon.

From the beginning of settlement, built-up areas were located on all past land cover categories. For example, the new settlements in the research area have resulted in the total disappearance of barren sparse dunes and ridges. In the past this type of land cover was considered poor quality land, just like the marshes. For this reason, infrastructures, roads, and settlements were built on this land cover. For example, the first coastal highway (highway no. 2) and Kibbutz Maagan Mikhael, Jisr as-Zarka, Bet Hananya, Or Aqiva, and the new settlement of Caesarea were all constructed on this type of land cover.

Despite the increase in population and settlements from the 1950s onward, almost all settlements were agricultural. However, from the end of the 1970s, the decline in demand for citrus and the general decline of the agricultural sector in Israel, together with the rise in land prices in the center of Israel, caused many who owned agricultural lands to cut down the orchards and sell the land.[69] The land was sold at a good price for the construction of new settlements and the expansion of existing ones. The process of urbanization in the Sharon region is very similar to the process that took place in the rest of the developed world.[70]

AGRICULTURAL EXPANSION

The 1881 PEF memoirs note that a "great part of the Plain of Sharon is uncultivated, except close to the villages."[71] Indeed, on the 1881 map the cultivated land cover is minimal. Gradually, though, the cultivated land cover area has increased. In 1881 cultivated land covered just 2.76 percent of the total research area. In the 1950s it reached 7.01 percent. Nonetheless, the great jump happened between 1954–58 and 2011, and by 2011 this land covered 37.70 percent of the total research area. Changes in cultivated land cover are directly linked to human settlement and activity and to national and global economic trends of supply and demand. From the 1950s on, the main branch of agriculture was citrus fruit in most settlements in the Sharon, as it was in great demand at that time in Europe.[72] The citrus industry prospered, orchard owners managed to recoup their investments, and with their profits they purchased more land and planted new orchards.[73] At their peak, near the end of 1975, citrus orchards covered 430 km^2 of the Sharon region.[74] At the end of the 1970s, due to the decline in demand for citrus in Europe, citrus trees were cut down and orchard areas became agricultural fields or built-up areas for the growing population in the region.[75] The 2011 source shows that more than half of the cultivated land covers are fields and less than half are still orchards.

AFFORESTATION

After the decrease in forest areas between 1881 and 1954–58, forests doubled in size between 1954–58 and 2011. Afforestation in Israel has a long history. Historically, the increase in forest areas was caused by forest planting as part of Jewish National Fund (JFN) operations.[76] At the beginning of the nineteenth century, the JFN began to purchase land in Palestine as part of the Zionist ideology. Once the land was purchased, the JNF began planting forests. This practice demarked land ownership and provided economic and employment prospects for new settlers. In addition, landowners could make use of the wood for commercial purposes. After the creation of the State of Israel and following the 1948 Arab-Israeli War, afforestation was also used to remove the abandoned Palestinian settlements from the consciousness of Israeli society.[77] From the end of the 1980s on, cultural attitudes toward forests changed. Afforestation practices continue to this day, but their main goals include creating leisure and recreational places and contributing to the natural environment and the preservation of nature.[78] The Israeli government has enacted various laws to protect forests and forest areas. In the last few years different private projects have been put forward with the aim of replanting new oak trees in the Sharon Plain in order to restore the forest to its past glory.[79]

CREATION OF ARTIFICIAL WATER BODIES

The creation of water bodies from the 1950s onward is linked to the challenge of floods that existed in this area for many centuries. One of the prayers spoken by Jewish high priests in the Second Temple period (around the first century AD) was a warning to the Sharon people to maintain their mud houses, lest they collapse upon them.[80] The Sharon region was known for yearly floods due to heavy rains in the winter season, which often caused mud houses to collapse. During excavations in 1924 near the town of Herzliya (see figure 1), researchers discovered an ancient Roman tunnel that had been built to drain the floodwaters.[81]

Even though the Sharon region has long suffered from floods, their increase can be linked directly to land cover changes. By the start of the twentieth century, the region had become bare due to the disappearance of forest areas.[82] Without forests, no trees could slow down the flow of water nor absorb it.[83] Many of the new Jewish settlers from 1881 onward established their settlements—such as Pardes-Hanna Karkur—on "empty" lands.[84] Since the new settlers had minimal knowledge of the area, they often settled in flat areas with water crossings, where land was cheap and less in demand. Moreover, until the 1930s they remained unaware that the groundwater in the area was high—another factor that increased the likelihood of floods. Furthermore, as previously mentioned, early Jewish settlers of the Sharon Plain removed marshes by draining their water into a nearby river.[85]

The appearance of water bodies on the 1954–58 map is linked to economic and political driving forces. Yearly floods damaged settlements, agricultural land, and property, both physically and economically. Since the creation of the State of Israel in 1948, the main solution to floods, like that used by early settlers, was to divert the water flow toward large rivers by building drainage channels and adapting the rivers to carry larger amounts of water.[86] Compared to the 1881 and 1917 sources, we can see that the 1954–58 and 2011 sources show that streams have drastically diminished. Today many water streams are underground channels. However, these actions created new challenges. Rivers received an increased water flow from other areas, which often caused them to overflow and flood the surrounding riverbanks and areas.[87] Due to the continuous flooding problem, the Drainage and Flood Protection Law was passed in 1957. This law established a statutory body called the Drainage Authority, whose main role was the protection and prevention of floods. The research area is also under two lesser draining authorities, the Sharon and the Carmel.[88] Since then, many efforts have been made to prevent and minimize flooding, especially in urban areas. Since 1969, part of the overflow of the Hadera River has been diverted for use at the Hadera power plant. Furthermore, the Drainage Authority established a dam on the Taninim River, which in wintertime diverts water to a sedimentation reservoir that enriches underground aquifers.[89] Another example is the establishment of special pools that collect water in times of need. These pools were constructed in the sand dune area near Caesarea, as well as near the Hadera River.[90] Lastly, in 2003, to successfully prevent constant flooding in the coastal highway (highway no. 2), an ancient Roman dam near Kibbutz Maagan Michel was reused.[91] Although many efforts have been made to reduce flooding in the Sharon Plain, it remains an issue during the winter months.[92]

CONCLUSION

This research has examined the forces behind the land cover changes in the northern part of the Sharon Plain (Israel). It found that these changes were significant and various. This study has demonstrated the existence of different proximate and underlying driving forces over different periods. Whereas in the first period of change cultural forces were dominant, in the second period it was a combination of political, socioeconomic, and cultural forces that led to changes. In the third period it was mainly political and socioeconomic forces. Moreover, this research illustrates how land cover changes are directly linked to the unique history of human development in the region. Some driving forces of land cover changes in the Sharon are similar to other places in the world—for example, the driving forces that reflect the transformations of human attitudes toward nature across different times, such as the drying of marshes, deforestation followed by afforestation, agricultural expansion, and present-day urbanization. Nonetheless, while similar cases to Sharon's land cover changes took place in other parts of Israel, driven by the same forces, the final changes were not always identical. An example of a different change is the drying of marshlands in the Hula Valley. In other cases the driving forces of land cover changes were similar to the ones in the Sharon, but the initial reasons for them were different. For example, at the end of the nineteenth century, some land cover changes in the Sharon Plain were the result of the new Jewish settlers' desire to solve problems they faced, such as diseases from the marshlands and floods. The reasons that brought the Jewish settlers to the Sharon Plain (i.e., Zionism) were different from the reasons of other settlers in other parts of the world. However, in similar conditions, the driving forces might have been the same in other parts of the world.

The advantage of using the approach of the driving forces is that it not only reveals the total outcome of LULC changes but also shows the dynamics in between the different LULC categories over time. Furthermore, this approach helps find the deep roots of LULC changes mostly hidden in various local/national narratives of different regions of the world, allowing us to compare the type, dynamic, and final result of the change. Through the identification of the driving forces and how they acted in a specific place and time, they can help effectively identify the right tools, policies, and solutions to manage the challenges faced at present better and reach a more sustainable future. Lastly, this research has stressed yet again the importance of historical maps as a source for understanding land cover changes over time.

ACKNOWLEDGMENTS

This research could not have been done without the kind help and access to cartographic materials from the Tel-Hai College Library Cartographic Collection and the Eran Laor Cartographic Collection at the Israel National Library. I would also like to thank Mr. Udi Grossman for his help with finding parts of the maps and Ms. Tom Feraro for proofreading this manuscript.

Lastly, I would like to thank the anonymous reviewers whose suggestions helped improve the clarity of the manuscript.

NOTES

1. Eric F. Lambin and Helmut J. Geist, *Land-Use and Land-Cover Change: Local Processes and Global Impacts* (Berlin: Springer-Verlag, 2006), 222; Tobias Plieninger, Helene Draux, Nora Fagerholm, Claudia Bieling, Matthias Bürgi, Thanasis Kizos, Tobias Kuemmerle, Jørgen Primdahl, and Peter H. Verburg, "The Driving Forces of Landscape Change in Europe: A Systematic Review of the Evidence," *Land Use Policy* 57 (2016): 204–14.

2. Eric F. Lambin, Mark D. A. Rounsevell, and Helmut J. Geist, "Are Agricultural Land-Use Models Able to Predict Changes in Land-Use Intensity?" *Agriculture, Ecosystems and Environment* 82, nos. 1–3 (2000): 321–31; Billie L. Turner II, Eric F. Lambin, and Anette Reenberg, "The Emergence of Land Change Science for Global Environmental Change and Sustainability," *Proceedings of the National Academy of Sciences of the United States of America* 104 (2007): 20666–71; Paul Selman, *Sustainable Landscape Planning: The Reconnection Agenda* (London: Routledge, 2012), 166.

3. Jianguo Wu, "Landscape Sustainability Science: Ecosystem Services and Human Well-Being in Changing Landscapes," *Landscape Ecology* 28, no. 6 (2018): 999–1023; Cyril O. Wilson, "Land Use/Land Cover Water Quality Nexus: Quantifying Anthropogenic Influences on Surface Water Quality," *Environmental Monitoring and Assessment* 187, no. 7 (2015): 1–23.

4. Abdullah F. Alqurashi and Lalit Kumar, "Investigating the Use of Remote Sensing and GIS Techniques to Detect Land Use and Land Cover Change: A Review," *Advances in Remote Sensing* 2, no. 2 (2013): 193–204; Smita Chaudhry, Priti Attri, and Subrat Sharma, "Remote Sensing and GIS-Based Approaches for LULC Change Detection—A Review," *International Journal of Current Engineering and Technology* 5, no. 5 (2015): 3126–37; Ian Gregory and Paul S. Ell, *Historical GIS: Technologies, Methodologies, and Scholarship* (Cambridge: Cambridge University Press, 2007), 203.

5. Gad Schaffer, Mor Peer, and Noam Levin, "Quantifying the Completeness of and Correspondence between Two Historical Maps: A Case Study from Nineteenth-Century Palestine," *Cartography and Geographic Information Science* 43, no. 2 (2015): 1–22.

6. Gad Schaffer and Noam Levin, "Challenges and Possible Approaches for Using GIS as a Tool in Historical Geography Landscape Research: A Meta-Analysis Review," *e-Perimetron* 10, no. 3 (2015): 94–123.

7. C. Nunes and J. I. Auge, eds., *Land-Use and Land-Cover Change (LULC) Implementation Strategy, IGBP Report 48* (Stockholm: IGBP, 1999), 125; Kleemann Janina, Gulendam Baysal, Henry N. N. Bulley, and Christine Furst, "Assessing Driving Forces of Land Use and Land Cover Change by a Mixed-Method Approach in North-Eastern Ghana, West Africa," *Journal of Environmental Management* 196 (2017): 411–42.

8. Nina Schneeberger, Matthias Bürgi, Anna M. Hersperger, and Klaus C. Ewald, “Driving Forces and Rates of Landscape Change as a Promising Combination for Landscape Change Research: An Application on the Northern Fringe of the Swiss Alps,” *Land Use Policy* 24, no. 2 (2007): 349–61; Matthias Bürgi, Anna M. Hersperger, and Nina Schneeberger, “Driving Forces of Landscape Change—Current and New Directions,” *Landscape Ecology* 19, no. 8 (2004): 857–68.

9. Helmut J. Geist and Eric F. Lambin, *What Drives Tropical Deforestation? A Meta-Analysis of Proximate and Underlying Causes of Deforestation Based on Subnational Case Study Evidence* (Louvain-La-Neuve: University of Louvain, 2001), 116.

10. Plieninger et al., “Driving Forces of Landscape Change.”

11. Gad Schaffer and Noam Levin, “Mapping Human-Induced Landscape Changes in Israel between the End of the 19th Century and the Beginning of the 21st Century,” *Journal of Landscape Ecology* 7, no. 1 (2014): 110–45.

12. Haim Goren, “Sacred, but Not Surveyed: Nineteenth-Century Surveys of Palestine,” *Imago Mundi* 54, no. 1 (2002): 87–110.

13. Israel Central Bureau of Statistics (website), *Localities and Population, by District, Sub-District, Religion and Population Group* (Jerusalem, 2018), https://www.cbs.gov.il/he/publications/DocLib/2018/2.ShnatonPopulation/st02_16x.pdf.

14. Yaron Lee, Rinat Zafrir, Avi Bar-Eli, and Rina R. Kandel, “Unusual Rainfall Floods Sharon-Area Streets, Leaving Thousands without Power,” *Haaretz*, October 29, 2015, https://www.haaretz.com/israel-news/.premium-unusual-rainfall-floods-sharon-area-streets-1.5414384.

15. Yukiko Hirabayashi, Mahendran Roobavannan, Koirala Sujan, Konoshima Lisako, Yamazaki Dai, Watanabe Satoshi, Kim Hyungjun, and Shinjiro Kanae, “Global Flood Risk under Climate Change,” *Nature Climate Change* 3, no. 9 (2013): 816–21.

16. Elie Bou-Zeid and Mutasem El-Fadel, “Climate Change and Water Resources in Lebanon and the Middle East,” *Journal of Water Resources Planning and Management* 128, no. 5 (2002): 343–55.

17. Lea Wittenberg, Haim Kutiel, Noam Greenbaum, and Moshe Inbar, “Short-Term Changes in the Magnitude, Frequency and Temporal Distribution of Floods in the Eastern Mediterranean Region during the Last 45 Years—Nahal Oren, Mt. Carmel, Israel,” *Geomorphology* 84, nos. 3–4 (2007): 181–91.

18. Noam Etzioni, *Israel Oak Registry*, 2019, https://survey123.arcgis.com/share/82017a6d17fa4cf7960cf55a7330c11f?open=menu.

19. Yoav Regev, ed., *The New Israel Guide: Shefela Foothills* (Jerusalem: Keter, 2001), 174.

20. Yehuda Karmon, “The Physiological Conditions of the Sharon and Their Influence on the Development of the Settlements” [Hebrew], *Bulletin of the Israel Exploration Society* 40–41 (1959): 137–60.

21. Bernhard Lehner, Kristine L. Verdin, and Andy Jarvis, “New Global Hydrography Derived from Spaceborne Elevation Data,” *Eos*, *Transactions of the American*

Geophysical Union 89, no. 10 (2008): 93–94; Israel Water Authority, *Ada-Taninim Waterbasin Map—Scale: Unknown* (Jerusalem, 2019).

22. Claude R. Conder and Horatio Kitchener, *Palestine Exploration Fund—Survey of Western Palestine 1:63,000 Map* (London: Palestine Exploration Fund, 1881).

23. Claude R. Conder, Horatio Kitchener, Horatio Herbert-Kitchener, Edward H. Palmer, and Walter Besant, *The Survey of Western Palestine: Memoirs of the Topography, Orography, Hydrography, and Archaeology* (London: Palestine Exploration Fund, 1882).

24. Noam Levin, "The Palestine Exploration Fund Map (1871–1877) of the Holy Land as a Tool for Analyzing Landscape Changes: The Coastal Dunes of Israel as a Case Study," *Cartographic Journal* 43, no. 1 (2006): 45–67.

25. War Office, *Palestine, Sheet 7 and 8 Caesarea, Map at a Scale of 1:63,360* (1917).

26. ESRI, DigitalGlobe, *World Imagery [Basemap], Resolution 0.5 Meters* (Redlands, CA: ESRI, 2011); *Survey of Israel, Yokneam Sheet, Map at a Scale of 1:50,000* (2014).

27. Noam Levin, "The Palestine Exploration Fund Map," 45–67; ESRI, *World Imagery [Basemap]*.

28. Schaffer and Levin, "Mapping Human-Induced Landscape Changes,"; Schaffer et al., "Quantifying the Completeness."

29. Avraham Faust, "The Sharon and the Yarkon Basin in the Tenth Century BCE: Ecology, Settlement Patterns and Political Involvement," *Israel Exploration Journal* 57 (2007): 65–82.

30. Mordehai Eliav, *Eretz Israel and Its Yishuv in the Nineteenth Century, 1777–1917* [Hebrew] (Jerusalem: Keter, 1978), 552.

31. Yehoshua Ben-Arieh, *The Making of Eretz Israel in the Modern Era, 1799–1949: A Historical-Geographical Study* (Jerusalem: de Gruyter Oldenbourg / Magnes, 2018), 713.

32. Yehuda Karmon, "The Physiological Conditions of the Sharon and Their Influence on the Development of the Settlements" [Hebrew], *Bulletin of the Israel Exploration Society* 40–41 (1959): 137–60.

33. Robert Stern, Meni Ben-Hur, and Isaac Shainberg, "Clay Mineralogy Effect on Rain Infiltration, Seal Formation and Soil Losses," *Soil Science* 152, no. 6 (1991): 455–62.

34. Maya Rotem, "Hedera Stream and the Environment" [Hebrew], *Ariel* 95–96 (1993): 189–93.

35. Yoav Waisel, ed., *Vegetation of the Land of Israel*: *Plants and Animals of the Land of Israel*, vol. 8 (Tel Aviv: Ministry of Defence and the Publishing House Society for Protection of Nature, 1984), 262; Rotem, "Hedera Stream."

36. Regev, *New Israel Guide*.

37. Baruch Rozen, "First Acclimatization of Eucalyptus Trees in Eretz Israel" [Hebrew], *Cathedra* 59 (1991): 95–102; Nili Lipschitz, "The Eucalyptus in Hedera: A Hundred Years of Eucalyptus Origin" [Hebrew], *Ariel* 95–96 (1993): 169–71.

38. Hilik-Yehial Mador-Haim, "Hadera—Malignant Swamps That Have Become a Flowering Garden" [Hebrew], in *Sipurei Moshavot*, 6th ed., ed. Zeev Aner (Tel Aviv: Israel Ministry of Defense, 2005), 260.

39. Shmuel Gadon, *Hedera 1890–1970* (Tel Aviv: Ministry of Education, 1992), 15.

40. Ran Aharonson, "The Baron Rothschild and Hadera" [Hebrew], *Ariel* 95–96 (1993): 33–40.

41. Shy Avitzur, "Hadera Forest and Its Uses" [Hebrew], in *Hedera and Surroundings: Sharon Park*, ed. Shiler Eli (Jerusalem: Ariel, 1993), 380.

42. Lipschitz, "The Eucalyptus in Hedera: A Hundred Years of Eucalyptus Origin."

43. William J. Mitsch and James G. Gosselink, *Wetlands* (Hoboken, NJ: Wiley, 2015), 456.

44. Maya Duany, "The Hula Nature Reserve as a Dialectical Response to the Hula Drainage Project," *Horizons in Geography* 78 (2012): 64–81.

45. Maya Duany and Emanuel Cohen-Shahar, "'When the Landscape Leaves You': The Level of Attachment to the Place as a Decisive Factor in the Reaction of Neighboring Communities to the Drying up of AHula" [Hebrew], *Ecology and Environment* 3 (2014): 254–62.

46. Omri Bone and Roi Harel, "The Sharon's Tabor Oak Forest Is Alive and Kicking" [Hebrew], *Yaar* 15 (2015): 64–71.

47. Zeev Vilnay, *Guide to Eretz Israel: Tel Aviv Sharon Hashfela and the Negev* (Tel Aviv: Tor Israel, 1950).

48. Israel Roll and Eitan Ayalon, *Apollonia and Southern Sharon: Model of a Coastal City and Its Hinterland* [Hebrew] (Tel Aviv: Hakibbutz Hameuchad and Israel Exploration Society, 1989), 134.

49. Waisel, *Vegetation of the Land of Israel*.

50. Yehuda Neeman, "The Glass Manufacturing Plant in Hadera during the Byzantine Period" [Hebrew], *Ariel* 95–96 (1993): 9–16.

51. Menashe Harel, "Gi-Harshim" [Hebrew], *Merchavim* 1 (1974): 49–62.

52. Karmon, "Physiological Conditions of the Sharon."

53. Bone and Harel, "Sharon's Tabor Oak Forest," 64.

54. Alexander Mather, "The Transition from Deforestation to Reforestation in Europe," in *Agricultural Technologies and Tropical Deforestation*, ed. Arild Angelsen and David Kaimowitz (Jakarta: CABI, 2001), 436.

55. Avraham Faust, "The Sharon and the Yarkon Basin in the Tenth Century BCE: Ecology, Settlement Patterns and Political Involvement," *Israel Exploration Journal* 57 (2007): 65–82; Avraham Fuess, "Rotting Ships and Razed Harbors: The Naval Policy of the Mamluks," *Mamluk Studies Review* 5 (2001): 45–71.

56. Lee I. Levine, *Caesarea under Roman Rule* (Leiden: Brill, 1975), 298; Gideon Foerster, "The Early History of Caesarea," *Bulletin of the American Schools of Oriental Research* 19 (1975): 9–22; Keith H. Beebe, "Caesarea Maritima: Its Strategic and Political Significance to Rome," *Journal of Near Eastern Studies* 42, no. 3 (1983): 195–207.

57. Faust, "The Sharon and the Yarkon Basin."

58. Conder et al., *Survey of Western Palestine*.

59. Oded Koralnik, *Principles of Geopolitics: An Attempt to a Geographical View of History* [Hebrew] (Tel Aviv: Taberski, 1951), 90.

60. Yehuda Karmon, "Geographical Influences on the Historical Routes in the Sharon Plain," *Palestine Exploration Quarterly* 93, no. 1 (1961): 43–60.

61. Hanna Margalit, "Some Aspects of the Cultural Landscape of Palestine during the First Half of the Nineteenth Century," *Israel Exploration Journal* 13 (1963): 208–23.

62. Yehoshua Ben-Arieh, *A City Reflected in Its Times: Jerusalem in the Nineteenth Century—Part 2—New Jerusalem—The Beginnings* [Hebrew] (Jerusalem: Yad Ben-Zvi, 1979), 699.

63. Ma'ayan Hess-Ashkenazi, "Arab Immigration to the Sharon Plain during the British Mandate Period," *Cathedra* 116 (2005): 103–16; Rivka Shpak-Lissak, *How the Arabs and the Muslims Migrated to the Land of Israel* (Rishon Lezion: Mishkal, 2018), 336; Ben-Arieh, *Making of Eretz Israel*.

64. Guy Keinan, "The Demographic History of the Sharon Region from the End of the Nineteenth Century Onward" [Hebrew], in *The Sharon: Between the Yarkon to the Carmel*, ed. Avi Dgani, David Grossman, and Avshalom Shmueli (Tel Aviv: Ministry of Defense and the Publishing House Society for Protection of Nature Israel, 1990), 441.

65. Noga Kadman, *Erased from Space and Consciousness: Israel and the Depopulated Palestinian Villages of 1948* (Bloomington: Indiana University Press, 2015), 280.

66. Erik Cohen, "Israel as a Post-Zionist Society" *Israel Affairs* 1, no. 3 (1995): 203–14; Howard M. Sachar, *A History of Israel: From the Rise of Zionism to Our Time* (New York: Alfred A. Knopf, 1976).

67. Gur Alroey, *An Unpromising Land: Jewish Migration to Palestine in the Early Twentieth Century* (Palo Alto, CA: Stanford University Press, 2014), 285.

68. Moshe Lissak, "The Demographic-Social Revolution in Israel in the 1950s: The Absorption of the Great *Aliyah*," *Journal of Israeli History* 22, no. 2 (2003): 1–31.

69. Dan Giladi, "The Citrus Harvest in the Sharon Region—Leveraging the Development of the Area" [Hebrew], in Dgani et al., *The Sharon*, 397–408.

70. Paul L. Knox and Linda McCarthy, *Urbanization: An Introduction to Urban Geography* (Harlow, UK: Pearson Prentice Hall, 2005), 594.

71. Conder et al., *Survey of Western Palestine*, 50.

72. Shelley Egozi, "The Pardess: An Israeli Symbolic Landscape," *Landscape Research* 22, no. 2 (1997): 175–89.

73. Dan Giladi, "Citriculture—An Impetus to the Intensification of Agriculture during the Mandate," *Proceedings of the World Congress of Jewish Studies* 2, no. 2 (1985): 115–19.

74. Menashe Davidzon, "The Jewish Citrus Industry in Israel during the 20th Century," *From Region to Environment: Forty Years of Geographical Studies at the University of Haifa* 64–65 (2005): 425–37.

75. Giladi, "Citrus Harvest."

76. Alon Tal, *All the Trees of the Forest: Israel's Woodlands from the Bible to the Present* (New Haven, CT: Yale University Press, 2013), 320.

77. Noga Kadman, *Erased from Space and Consciousness: Israel and the Depopulated Palestinian Villages of 1948* (Bloomington: Indiana University Press, 2015), 280.

78. John Stemple, "Viewpoint: A Brief Review of Afforestation Efforts in Israel," *Rangelands* 20, no. 2 (1998): 15–18.

79. Etzioni, *Israel Oak Registry*, https://survey123.arcgis.com/share/82017a6d17fa4cf7960cf55a7330c11f?open=menu.

80. Jerusalem Talmud, Yuma 5, B.

81. Karmon, "Physiological Conditions of the Sharon,".

82. Eva Ritter and Dainis Dauksta, eds., *New Perspectives on People and Forests*, vol. 9 (Dordrecht: Springer, 2011), 268.

83. Michael B. Shapiro, "Soils of Israel," *Eurasian Soil Science* 39, no. 11 (2006): 1170–75.

84. Karmon, "Physiological Conditions of the Sharon."

85. Rozen, "First Acclimatization of Eucalyptus Trees," 95–102; Lipschitz, "Eucalyptus in Hedera."

86. Rotem, "Hedera Stream."

87. Moti Kaplan and Yaara Rosner, *The River and the City: Both Went Together* [Hebrew] (Jerusalem: Israeli Ministry of Environmental Protection and Jerusalem Institute for Policy Research, 2011), 121.

88. Sharon Drainage Streams Authority (Website), "*Sharon Drainage and Streams Authority*" [Hebrew], 2018, http://www.rnsharon.org.il/?page_id=54; Carmel Drainage Streams Authority (Website), *Carmel Drainage and Streams Authority* [Hebrew], 2019, http://www.nikuzcarmel.co.il/תושרה-תודוא/.

89. Yehuda Peleg, "Water Reservoirs and Low Aqueducts of Caesarea" [Hebrew], *Cathedra* 56 (1990): 19–32.

90. Ido Batchko and Micha Klein, "Menashe Streams Plants and Dune Plantation" [Hebrew], *Horizons in Geography* 70 (2008): 32–41.

91. Carmel Drainage Streams Authority (Website), *The Ancient Dam on Taninim River* [Hebrew], https://www.nikuzcarmel.co.il.

92. Department of Geography (Website), *Floods in Israel*, Haifa University, 2016, https://geo.hevra.haifa.ac.il/~inh/index.php?option=com_content&view=article&id=88:floods-in-israel&catid=36&lang=en&Itemid=277.