Universidad de Valladolid

Master Erasmus Mundus in
Mediterranean Forestry and Natural Resources
(MEDFOR)

Land cover changes in the Eastern Mediterranean Ecosystem: The case of Haifa and Jerusalem Metropolitan areas

Student: Mulugeta Sisay Abebe

Co-advisors: Gad Shaffer (Ph.D.)
Pablo Martin Pinto (Ph.D.)

Palencia, July 2019

Co-funded by the
Erasmus+ Programme
of the European Union

Table of Contents

List of Appendix

List of Figures

List of Tables

RESUMEN

Este documento examina los cambios en la cobertura terrestre comparando dos períodos de tiempo, 1881 y 2019. Para este propósito, comparamos la cobertura terrestre derivada del mapa histórico del Fondo de Exploración de Palestina con una cobertura terrestre actual. El objetivo principal de este estudio fue mapear y examinar la cobertura terrestre desde 1881 hasta 2019, analizar cómo se transformó cada cobertura terrestre entre 1881 y 2019 e investigar la fragmentación de la cobertura terrestre en el tiempo y el espacio en el área metropolitana de Haifa y Jerusalén. La clasificación de la cubierta terrestre, el mapeo y la detección de cambios se realizaron en el entorno de ArcGIS, mientras que la fragmentación de la cubierta terrestre se examinó utilizando métricas de paisaje de FRAGSTATS. La transformación de la cobertura terrestre se clasificó en siete clases: tierras agrícolas, urbanizadas, forestales, espacios abiertos, matorrales, cuerpos de agua y bosques. En el área de Haifa, se identificaron seis clases de cobertura terrestre, excepto el cuerpo de agua. Los bosques fueron la cobertura de tierra dominante (26,439 ha que fue 59.1%) en el pasado, mientras que en la actualidad, las tierras de bosque (15,683 ha que fue 35%) fueron la cobertura de tierra dominante que otras categorías en el área de Haifa. En Jerusalén, la clasificación y el resultado de la cartografía identificaron tierras agrícolas, áreas edificadas, espacios abiertos, matorrales y bosques en el pasado. Por otro lado, en la actualidad, las tierras forestales y el cuerpo de agua se identificaron además de lo que ya se identificó en el pasado. Las tierras forestales y el cuerpo de agua estuvieron ausentes en el pasado. En la actualidad, las tierras forestales (16,606 ha que fueron 33.9%) son las coberturas dominantes en el área metropolitana de Jerusalén. Los resultados de la transformación de la cubierta terrestre en el área metropolitana de Haifa revelaron una disminución sustancial en el bosque (-43.7%) con el tiempo. Alrededor del 20.5% de los bosques se convirtió en terrenos edificados y agrícolas en esta área. En el área de Jerusalén, la segunda cobertura porcentual más alta de matorrales (23%) se convirtió en un edificio. Por otro lado, se observó un incremento sustancial en la cubierta forestal en ambas áreas estudiadas. El programa nacional masivo para recuperar y restaurar el paisaje mediterráneo degradado de Israel tiene un papel importante en el aumento de la cubierta forestal en las áreas estudiadas a lo largo del tiempo. El resultado también mostró tendencias dinámicas de variación temporal y espacial en la fragmentación de la cubierta terrestre. El número de parches fue relativamente más alto en el presente período. Se observó una mayor probabilidad de dispersión en las categorías de tierras forestales y tierras boscosas. Woodland en PEF y Forest land en la actualidad tenían el IJI más alto en el área de Haifa. Por otro lado, el espacio abierto en PEF y las tierras agrícolas en la actualidad tenían el IJI más alto en el área de Jerusalén. Un aspecto importante que se destaca del estudio es que la fragmentación parece estar impulsada por la necesidad de desarrollo socioeconómico de la creciente población en las áreas estudiadas. En general, este estudio proporciona un conocimiento importante sobre los patrones espacio-temporales de cobertura de la tierra en las áreas estudiadas y cada uno de los resultados tiene un papel fundamental que desempeñar en la planificación de los trabajos de conservación que tienen como objetivo proteger las cubiertas de tierra frágiles que están sujetas a perturbaciones antropogénicas en las áreas estudiadas. .

Palabras clave: Fragmentación, GIS; mapas historicos; cobertura del suelo transformación / cambios

ABSTRACT

This paper examines changes in land cover by comparing two time periods, 1881and 2019. For this purpose, we compared land cover derived from the Palestine Exploration Fund historical map to a present land cover. The main objective of this study was to map and examine land cover from 1881 to 2019, to analyze how each land cover was transformed between 1881 and 2019 and to investigate land cover fragmentation in time and space in the Haifa and Jerusalem metropolitan area. Land cover classification, mapping, and change detection were done in the ArcGIS environment while land cover fragmentation examined using FRAGSTATS landscape metrics. The land cover transformation was categorized into seven classes: agricultural land, built-up, forest land, open space, scrubland, water body, and woodland. In Haifa area, six land cover classes except water body were identified. Woodland was the dominant land cover (26,439 ha which was 59.1%) in the past while in the present day, forest land (15,683 ha which was 35%) was the dominant land cover than other categories in Haifa area. In Jerusalem, the classification and mapping result identified agricultural land, built-up, open space, scrubland and woodland in the past. On the other hand, in the present day, forest land and water body identified in addition to what has been already identified in the past. Forest land and water body were absent in the past. In the present day, forest land (16,606 ha which was 33.9%) is the dominant land cover in Jerusalem metropolitan area. Land cover transformation results in Haifa metropolitan area revealed that a substantial decline in woodland (-43.7%) with time. About 20.5% of woodland was converted to Built-up and agricultural land in this area. In Jerusalem area, the second-highest percentage cover of scrubland (23%) was converted to built-up. On the other hand, a substantial increment in forest cover in both studied areas was observed. Massive national program to reclaim and restore Israel's degraded Mediterranean landscape has a significant role in increasing forest cover in the studied areas over time. The result also showed dynamic temporal and spatial variation trends in land cover fragmentation. Patch number was relatively higher in the present period. A greater probability of dispersion in the forest land and woodland categories was observed. Woodland in PEF and Forest land in the present day had the highest IJI in Haifa area. On the other hand, Open space in PEF and agricultural land in the present day had the highest IJI in Jerusalem area. One important aspect which stands out from the study is that fragmentation seems to be driven by socioeconomic development need of the growing population in the studied areas. Generally, this study provides important knowledge on spatiotemporal land cover patterns in the studied areas and each of the results has a fundamental role to play on planning conservation works that aim to protect fragile land covers that are subjected to anthropogenic disturbances in the studied areas.

Keywords: Fragmentation, GIS; historical maps; land cover; transformation/changes

1. INTRODUCTION

Land cover is always in a dynamic state of change as a result of natural and anthropogenic activities (Burgi et al., 2005). It has been altered and modified since pre-history (Pal & Ziaul, 2017), as a result of the interaction between anthropogenic and biophysical factors (Addae & Oppelt, 2019). These interactions are different in every region, meaning that land covers are impacted and modified in different ways. It is influenced by a combination of several factors and no single factor can solely account for these changes.

In the past two centuries, the impact of human activities on land has increased enormously, altering entire landscapes, and ultimately impacting the earth abiotic components (climatic and edaphic factors) and other biotic components worldwide (Lambin & Geist, 2011). In the dynamic process of change in land cover, natural resources are the major focus among all forms of natural and human-induced changes (Zengin et al., 2018). The human dependency on natural resources for survival, coupled with ever-increasing population (United Nations, 2017) often unrestricted demands and imprudent use, has exerted considerable pressure on nature and its fragile components (Geist et al., 2006). Thus, through these demands, humans have been changing the natural resource base in various ways and intensities (Stéphenne & Lambin, 2001).

Research interests in land cover change over the last few decades have led to numerous researches. The focus was on recognizing and quantifying land cover, understanding the nature and causes of the change, projecting its future trends, assessing its social and economic costs and benefits, and examining its impact on ecosystems and biophysical processes (Schaffer & Levin, 2014). For instance, research output indicates an intensive human disturbance in the past resulted in land cover changes and thereby the formation of highly heterogeneous land cover in Mediterranean region (Bar Massada et al., 2009; Willis, 2001).

The present study was carried out in Israel, the country with unique geographical and historical diversity (Kaplan, 2011). The country has a very diverse set of ecosystems ranging from temperate to tropical (Israel Ministry of Foreign Affairs, 2013), Mediterranean climate that is conducive to forest development (Tal, 2012) and desert ecosystem (Kaplan, 2011). This is due to the variation in topography, climate, vegetation, and prolonged influence of human activity which together creates a varied landscape and diverse ecosystem (Médail & Quézel, 1999).

Human has lived in all regions of Israel since before biblical times and in the last hundred years, human activities and over-exploitation of natural resources have created continuous land cover changes (Brand et al., 2008). Thus, land use activities whether converting natural landscapes for human use or changing management practices on human-dominated lands have transformed a large proportion of Israel's landscape. For instance, the Mediterranean regions and desert frontiers were covered by forests prior to the country's settlement (Kaplan, 2011).

Although vast expanses of a dense forest may not be a typical image in the past, forests play a major ecological role in Israel and have always been a fundamental factor in the life of its inhabitants (Brand et al., 2008). The close relationship that has developed over time between humans and the forest has sometimes been stable, but more often it has been out of balance and detrimental to forests that are notable for their fragility (Braverman, 2015). There is some evidence that the oak trees in the coastal area were used as combustible materials for the glass factory in the Byzantine period around 300-630 AD (Neeman, 1993). There is also evidence that the Crusaders used the woods of this region for their iron industry (Harel, 1974). Later, during the First World War, 1914-1918, the Ottoman Empire continued to alter the forest and cut down more woods to operate the Ottoman steam trains and for the war efforts (Bone and Harel 2015). As a result, over the course of the twentieth century, the forest and natural vegetation cover of Israel were subjected to continuous changes (Schaffer & Levin, 2014; Yom-Tov et al., 2012).

Since its establishment in 1948, the state of Israel has embraced sustainable management and has adopted public policies designed to restore, develop and manage its natural resources. In the first pioneering stage of afforestation in Israel which was initiated at the beginning of the 20th century, about 240 million trees have been planted and regulations have been introduced with the objective to control grazing and ensure effective water management (Braverman, 2015). Massive afforestation by Israeli Forest Service (Keren Kayemeth LeIsrael (KKL)/ Jewish National Fund (JNF)) was driven by both a desire to address the pervasive unemployment associated with massive immigration of Jewish refugees and to fulfill an ideological mission of "restoring" a damaged promised land (Tal, 2012).

Moreover, the Israeli Forest Service launched a policy that encouraged the adoption of sustainable forest management practices for planted forests. In 1995, the Israeli Government ratified a new National Master Plan for Forests and Forestry (NMP 22). Approval of this plan expanded KKL/JNF jurisdiction to areas beyond those of the planted forest landscapes, giving statutory status to around eight percent of Israel's land. The plan affects 160,000 hectares of existing and proposed forestlands, covering approximately 7.3 percent of Israel's total land surface which is 22,000 square kilometers. Thus, KKL considered as the most powerful single organized entity to have shaped the modern Israeli landscape (Braverman, 2015).

Managing natural resources and monitoring environmental change becomes a central constituent in current strategies worldwide (Wang & Feng, 2008). Hence, understanding land cover changes have paramount importance. For instance, US National Academy of Sciences reinforced a law in 2001 for addressing land cover change related issues following the identification of land cover changes as one of the most pressing environmental challenges (Pickett & McDonnell, 2011), that require immediate research investment. Furthermore, the rapid development of the concept of vegetation mapping has led to increased studies of land cover change worldwide. Providing an accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources have become an important priority.

Furthermore, it is essential to understand the land cover to detect changes, predict as well as monitor ecological systems and it is useful for rational planning activities (Dale et al., 2000). Technological advancement in the last 35 years to support decision making in natural resource management and monitoring provide a range of possibilities for land cover change studies (Lillesand et al., 2015). Such decisions support tools such as Geographic Information System (GIS) were used in this study. In this research, study emphasis was given to map, assess, and quantify land cover changes and its fragmentation by using the integrated techniques of Remote sensing and GIS technology to keep up with the latest advances in this knowledge domain.

2. OBJECTIVES

2.1. General Objective

The main objective of this study was to map and examine land cover changes as well as to investigate its fragmentation in time and space in the Haifa and Jerusalem metropolitan area.

2.2. Specific Objectives

- To map and compare each land cover from 1881 to 2019 in the studied area.
- To analyze how each land cover was transformed between 1881 and 2019.

- To model land cover fragmentation in time and space in the studied area.

3. MATERIAL AND METHODS

3.1. Study site

The present study was carried out in Israel, the country with unique geographical and historical diversity (Schaffer & Levin, 2014). The area encompassing Israel (22,000 square kilometers), located in the eastern Mediterranean region between the Mediterranean Sea and the Jordan River. It lies between latitudes 31.0461° N and longitude 34.8516° E on the verge of the Saharo-Arabian desert belt and has been inhabited by humans for approximately one million years (Yom-Tov et al., 2012). The country has a very diverse set of ecosystems ranging from temperate to tropical (Israel Ministry of Foreign Affairs, 2013), Mediterranean climate that is conducive to forest development (Tal, 2012) and desert ecosystem (Kaplan, 2011). This is due to the variation in topography, climate, vegetation, and prolonged influence of human activity which together creates a varied landscape and diverse ecosystem (Médail & Quézel, 1999). The present study focuses on two populous metropolitan areas Haifa (Fig 1a) and Jerusalem (Fig 1b).

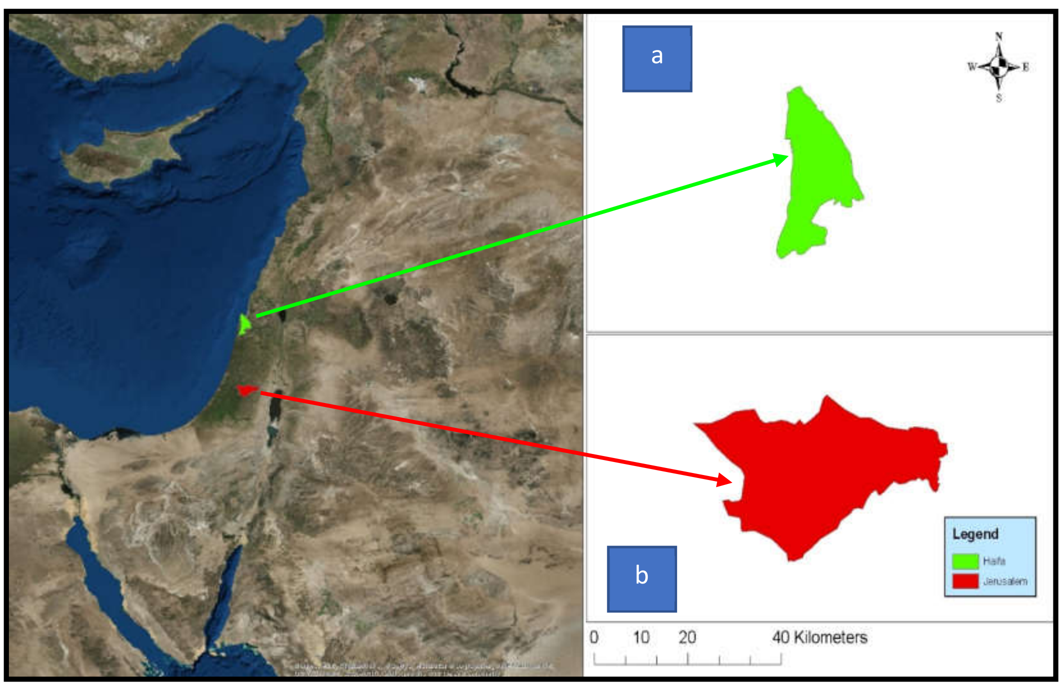


Figure 1. The study area (Haifa (a) and Jerusalem (b))

Haifa is Israeli's third Largest city and situated on the Israeli Mediterranean climatic section bordered with Mediterranean coastal Plain located between 32.7940° N and 34.9896° E. Haifa is the historic land bridge between Europe, Africa, and Asia located 90 kilometers north of Tel Aviv. Built on the slopes of Mount Carmel, the settlement has a history spanning more than 3,000 years (Jewish Virtual Library, n.d.). Haifa has a hot summer Mediterranean Climate with hot dry summers and cool, rainy winters. The average temperature in summer is 26°C and in winter 12°C, however, temperature around 3°C sometimes occur. Humidity tends to be high all year round, and rain usually occurs between September and May. Annual Precipitation is approximately 629 millimeters (www.timeanddate.com).

Jerusalem is the largest city in Israel population wise, is a city located on the plateau in the Judaean Mountains between Mediterranean and Dead Sea 60-kilometer east of Tel Aviv. Located at 31.76904 latitudes, and 35.21633 longitudes. The whole of Jerusalem is surrounded by valleys and dry riverbeds. The area is characterized by a hot summer Mediterranean climate, with hot, dry summers, and mild, wet winters. January is the coldest month of the year, with an average temperature of 9.0°C; July and August are the months, with an average temperature of 24.2°C, and the summer months are usually no rain. The average annual precipitation is around 537 mm, with rain occurring almost entirely between October and May. The highest recorded temperature in Jerusalem was 44.4°C on 28 and 30 August 1881, and the lowest temperature was -6.7°C in January 1907 (www.timeanddate.com).

Generally, Israeli landscape has been shaped by the Israeli Forest Service (Braverman, 2015). The forest lands (Table 1) are distributed as 59 percent in the northern and central Mediterranean regions characterized by natural Mediterranean *oak* trees, *pistachio*, *Aleppo pine* and *carob* and 41 percent in the semi-arid southern region where species like *Isolated pistachio* (*Pistacia atlantica*) and *Christ's thorn* (*Zizyphus spinachristi*) are native to this region.

Table 1. Five categories of forest assigned by NMP 22

Types	Area (ha)	Percentage
Planted forest	65,900	41
Natural forest	60,000	37
Park forest	26,000	17
Costal park forest	4,200	3
Riparian plantings	3,900	2

Source: (Brand et al., 2008)

3.2. Input data and sources

To address the objectives of this research a historic map of the Palestinian Exploration Fund (PEF) was used. Using historical maps to understand past land cover is indispensable and is a dependable source of information. The map was prepared by the Royal Engineers Corps between 1871-1877 and published in 1881 by the Palestine Exploration Fund, in Britain (Schaffer & Levin, 2014). It was georeferenced using 123 control points of trigonometrical stations and 1st order polynomial, with a root squared error of 74.4 meters (Levin, 2006). The map includes about 18 land cover classes (Appendix 1) of both natural and artificial features of Palestine with detail scale (1:63,360) and it is considered as the first accurate topographic map of Palestine[1]. Therefore, in this research PEF map was used to depict the past land cover of the study areas. Several studies have also used the PEF survey map as a source to depict 19th century land cover of Palestine (Levin, 2006).

[1] Until 1948 the land was called Palestine.

Table 2. Materials used in this research

Material used	Category	Spatial Resolution	Publisher
PEF	Digital map	20X20	ESRI ArcGis map service
2019 Satellite data of the study areas	Image		ESRI world imagery
DEM	Image	30X30	NASA-ASTER
Software used			
Arc GIS	10.6.2		ESRI Version 10.6.2
FRAGSTATS	Version 4		(McGarigal, 2012)

NB: The spatial resolution for all data used in this research were changed to 30X30 meters during analysis.

On the other hand, for mapping the present land cover, the satellite image from google earth (2019) was used as there was no nationwide land cover mapping available for Israel detailing natural vegetation classes (Schaffer & Levin, 2014).

3.3. Methods and analysis

3.3.1. Land cover classification in 1881 and 2019

Classification is a process by which a set of items is grouped into classes based on common characteristics. The land cover classification was done between images/map classification of the same scene at different times for both periods. Thus, in this research, both PEF map and satellite image of the present day (2019) were digitized. The scale of 1:20,000 was used. To identify the features on PEF map during digitization, keys for land cover have been used (Appendix 1).

Table 3. Definitions of Land cover classes mapped in this research

Land cover category	Definition
Agricultural Land **(AL)**	Annual crops, Arable Lands, Permanent Crops and Pastures
Built up **(BU)**	Airports, Construction sites, excavation sites, Industrial and commercial areas, Ports, Residential areas, Transportation networks
Forest Land **(FL)**	Areas covered with trees which are planted or natural in their origin
Open Space **(OS)**	Bare rock, bare soil
Scrubland **(SL)**	Areas covered by shrub and herbaceous vegetation
Water Body **(WB)**	Lakes, reservoirs, rivers
Woodland **(WL)**	Areas with scattered tree covers

After digitization of both studied area, an attribute table with a description of the land cover name was recorded for each digitized section of land cover. The symbology tool was used to categorize the recorded land covers in their respective category (Table 3). Finally, the classified map and image was used to calculate the area of different land cover and observe the changes that are taking place.

3.3.2. Land cover transformation (1881 – 2019)

Land cover change detection has become a central component in current strategies for managing natural resources and monitoring environmental changes. With change detection, it is possible to quantify the rate of change and understand the source and destination of land cover changes occurred in a place. Therefore, land cover confusion matrix was generated using ArcGIS Intersect tool for the classified image at different period of both study area.

Land cover increasingly threatened by rapid infrastructure development and agricultural expansion (Laurance & Balmford, 2013). As a result, land cover especially vegetation cover in the proximity of built-up and agricultural land influenced in many ways. Thus, to analyze the impact of infrastructure and agricultural activity effect on vegetation cover neighbor analysis were carried out in the ArcGIS environment. The classified map for both periods of the studied area treated in Analysis tool and Polygon Neighbors was used to analyze the edge length share between vegetation cover and built-up and agricultural land.

To analyze the dynamics of land cover changes across slope Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (DEM) were downloaded from Aeronautics and Space Administration (NASA) (NASA Jet Propulsion Laboratory, 2004). The slope was generated using surface analysis tool in ArcMap. The slope classes were categorized following the standard of Barcelona field study center slope classification approach (https://geographyfieldwork.com). Then, once the slope was generated overlay analysis was carried out against both present and past maps to see the land use and land cover dynamics across different slope classes.

3.3.3. Modeling land cover fragmentation

To model the land cover fragmentation in time and space FRAGSTATS software was used and FRAGSTATS Landscape metrics were extracted from classified images. According to Millington, et al. (2003), FRAGSTATS has a distinct nature and capacity to estimate landscape behavior characteristics, and therefore relevant in land cover fragmentation studies (Vogelmann, 1995). Several studies (Cushman et al., 2012; Millington et al., 2003) also were carried out using FRAGSTATS to understand the characteristic behavior of the landscape in time and space.

Firstly, the classified images were converted to ASCII format in ArcGIS and the raster version of the classified image in FRAGSTATS was applied using the 16-cell rule following McGarigal & Marks (1995) recommendation. ASCII format scenes were imported into FRAGSTATS. Then, ASCII built-in algorithm selected for running analyses in the FRAGSTATS model. Metrics relevant in explaining the magnitude and extent of fragmentation were selected (Cushman et al., 2012). All metrics (Patch, Class, and Landscape) were selected from the PEF and Present image scenes. For the statistical analyses, a patch area is a useful metric in landscape analysis as (McGarigal & Marks, 1995) therefore, patch area metric were used for testing the magnitude of fragmentation.

4. RESULTS

4.1. Land cover classification in 1881 and 2019

The land cover classes of Haifa metropolitan area during 1881 (PEF) (Fig 2a) includes agricultural land, built-up, forest land, open space, scrubland, and woodland. As indicated in Table 4, the greatest share of land cover classes was woodland which covered an area of 26,439 hectares (59.1%). Open space located in the north and scrubland in central and southern part covered 8,037 hectares (17.9%) and 5,170 hectares (11.6%). Out of the total 44,755 hectares in Haifa metropolitan area, 3,438 (7.68%), 1,566 (3.5%), 104 (0.2) hectares were covered by forest land, agriculture land and built-up, respectively.

Table 4 Land cover of the study area (Haifa) between 1881 and 2019

Land cover Category	PEF		Present		Total percentage difference
	Area (Ha)	%	Area (Ha)	%	
Agricultural Land	1566	3.5	4622	10.3	6.8
Built Up	105	0.2	8574	19.2	18.9
Forest Land	3438	7.7	15683	35.0	27.4
Open Space	8037	17.9	5552	12.4	-5.6
Scrubland	5170	11.6	3454	7.7	-3.8
Woodland	26439	59.1	6870	15.4	-43.7
Grand Total	**44755**	**100.0**	**44755**	**100.00**	**0.0**

On the other hand, the present (2019) image classification (Fig 2b) results in the highest share covered with forest which is 15,683 hectares (35.0%) (Table 4). The result also shows that 8,574 hectares (19.2%) of the area is covered with built-up which is mainly found at the north and close to the Mediterranean Sea. During this time, 6,870 hectares (15.4%), 5552 hectares (12.4%), 4,622 hectares (10.3%) and 3,454 hectares (7.7%) area were covered by woodland, open space, agricultural land, and scrubland, respectively.

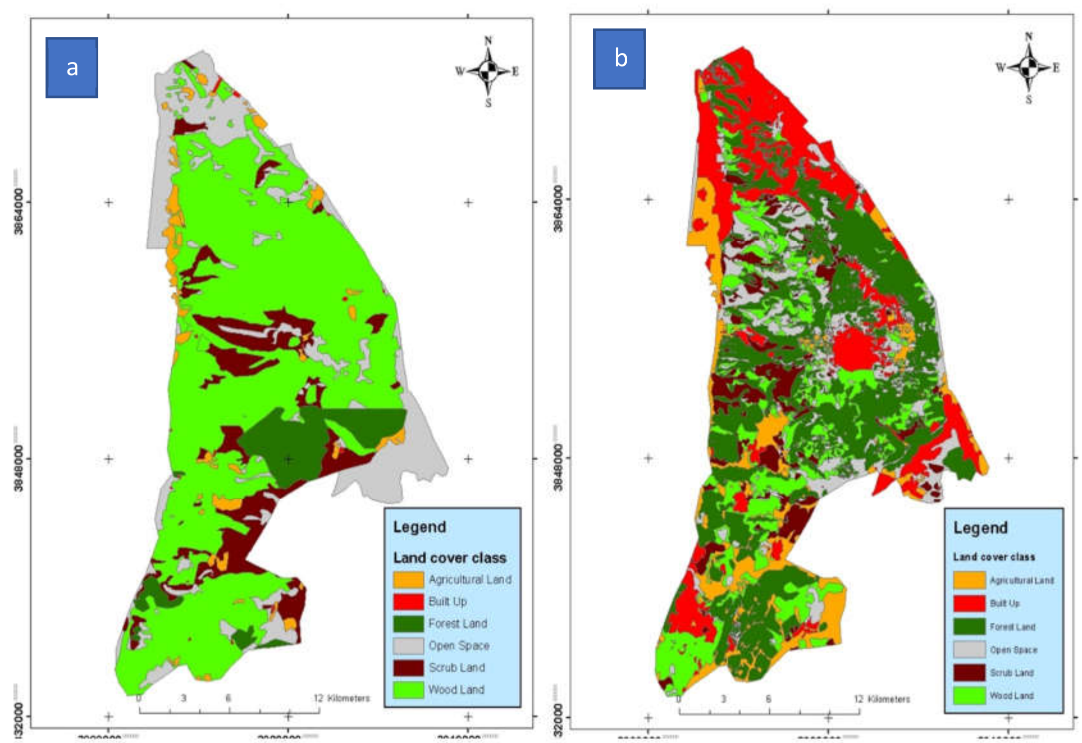


Figure 2 Land cover map of Haifa Metropolitan area. (a) PEF 1881 and (b) Present 2019

In Jerusalem, the highest share 29,547 hectares (60.2%) were covered by open space in the past (Table 5) followed by scrubland which covers 12,766 (26.0%). Agricultural land and woodland cover 4,358 hectares (8.88%) and 2,129 (4.3%), respectively. Most of the agricultural land was close to built-up covers (Fig 3a). During 1881 built-up cover less than 1% share of the land cover which was 258 hectares.

Table 5 Land cover of the study area (Jerusalem) between 1881 and 2019

Land cover Category	PEF		Present		Total percentage difference
	Area (Ha)	%	Area (Ha)	%	
Agricultural Land	4358	8.9	6324	12.8	4.0
Built Up	258	0.5	8506	17.3	16.8
Forest Land	0	0.0	16606	33.9	33.9
Open Space	29547	60.2	7247	14.8	-45.5
Scrubland	12766	26.0	4158	8.5	-17.6
Water Body	0	0.0	101	0.2	0.2
Woodland	2129	4.3	6117	12.5	8.1
Grand Total	**49057**	**100**	**49057**	**100**	0.0

The present classification shows that forest land has the highest share stretching from north to south and concentrated in the central part (Fig 3b). Meanwhile, built-up covers 8,506 hectares (17.3%), agricultural land 6,324 hectare (12.9%) and woodland covers 6,117 hectares (12.5%). Scrubland cover 4,157 hectares (8.5%) of the land. The new land cover category in the present classification that was not the case in PEF is waterbody which covers 101 hectares (0.2%) of the area (Table 5).

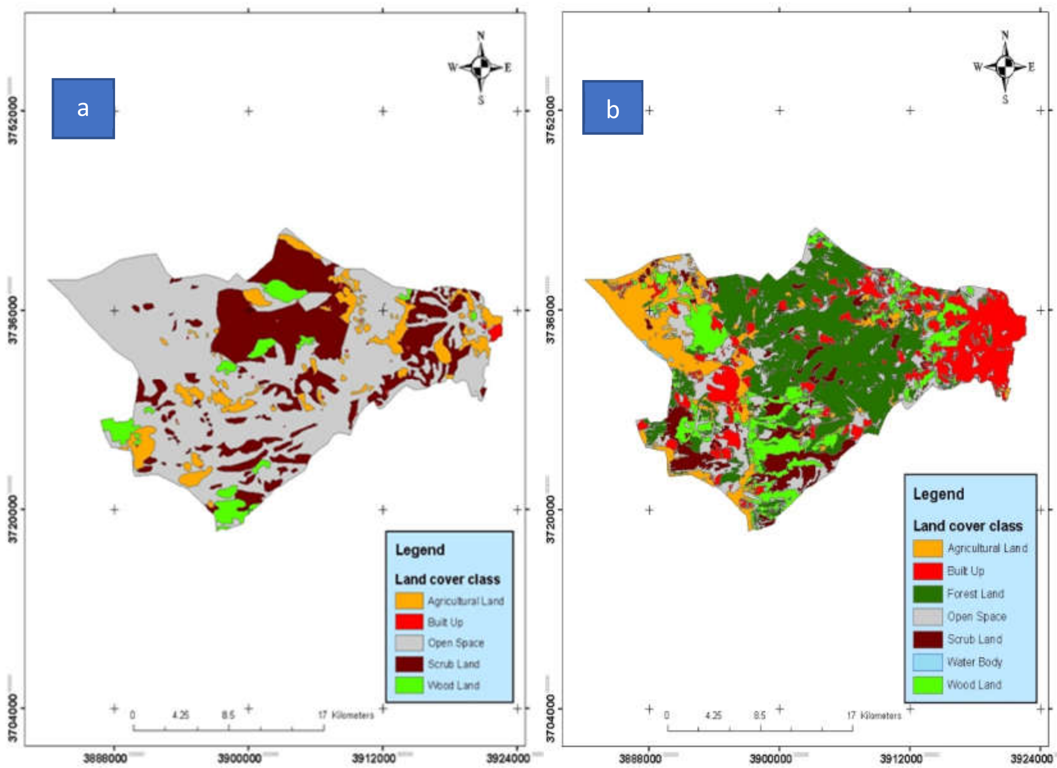


Figure 3 Land cover map of Jerusalem Metropolitan area ((a) PEF 1881 and (b) Present 2019)

4.2. Land cover transformation (1981-2019)

4.2.1. Land cover transformation in Haifa Metropolitan area

The land cover change detection result indicates a significant land cover change of the studied areas. The land cover matrix (Tables 6 & 7) indicates the course and the area extent of the change. The diagonals are the areas of the land covers that remain the same while the nondiagonal's are the change. The change detection analysis of Haifa metropolitan area shows the highest increment in the spatial extent of forest land with the total percentage difference of +27.4% followed by built-up +18.9% (Table 4). On the contrary, woodland, Open Space and scrubland area coverage decreased.

The highest change was observed in woodland area (-43.7%) (Table 4). From the total area covered by woodland 26,439 (59.08%) in PEF, 11,091 hectares (42%) changed to forest land, 3,750 hectares (14.18%) changed to built-up, and 1,665 hectares (6.3%) were converted to agricultural land in the present period (Table 6). Only 4,572 hectares (17.3%) remain the same, while 2,212 hectares (11.9%) were converted to open space. The significant change in forest land from 3,438 hectares to 15,683 hectares were resulted from the afforestation initiative by KKL/JNF at the beginning of the 20th century. Since the establishment of Israel in 1948, KKL/JNF has embraced sustainable management and has adopted public policies designed to restore, develop and manage natural resources across the country which positively contributed to positively significant forest cover change.

Table 6 Land cover confusion Matrix Haifa metropolitan area

Land Cover Category		Present												
		AL	**%**	**BU**	**%**	**FL**	**%**	**OS**	**%**	**SL**	**%**	**WL**	**%**	**Grand Total**
PEF	**AL**	**509**	11.0	503	5.9	189	1.2	86	1.6	54	1.6	224	3.3	**1566**
	BU	3	0.1	**64**	**0.7**	13	0.1	16	0.3	6	0.2	3	0.0	**105**
	FL	98	2.1	260	3.0	**1610**	**10.3**	461	8.3	171	5.0	837	12.2	**3438**
	OS	1233	26.7	3537	41.3	1326	8.5	**1090**	**19.6**	294	8.5	558	8.1	**8037**
	SL	1114	24.1	459	5.4	1454	9.3	749	13.5	**718**	**20.8**	676	9.8	**5170**
	WL	1665	36.0	3750	43.7	11091	70.7	3149	56.7	2212	64.0	**4572**	**66.5**	**26439**
	Grand Total	**4622**	**100.0**	**8573**	**100.0**	**15683**	**100.0**	**5552**	**100.0**	**3454**	**100.0**	**6870**	**100**	**44755**

AL= Agricultural Land, BU= Built-up, FL=Forest Land; SL=Scrubland, WL=Woodland

The result also shows an incremental change in built-up category. In PEF the total area under built-up was 104 hectares. At the present day, built-up area coverage increases to 8,573 hectares mainly at the expense of woodland (43.7%) and open space (41.3%) category (Table 6). The increase in agricultural land area from 1,566 in PEF to 4,622 in present time is mainly attributed to a relatively higher area of woodland (36%), open space (26.7%) and scrubland (24.1%) change. Land cover confusion matrix (Table 6) indicates of 104 hectares of built-up area in PEF, 64 hectares remain the same in present time. The main reason is that some of the villages were abandoned following the war in the country at a different time between the years.

4.2.2. Land cover transformation in Jerusalem Metropolitan area

The major land cover classes of the Jerusalem area in PEF include agriculture land, built-up, open space, scrubland, and woodland. Forest land and water body were not present in Jerusalem area during 1881. As indicated in Table 7, built-up, woodland and agricultural land have been increased positively while open space and scrubland have been decreased over areal coverage between the years. At the present day, (16,606) hectares which are 33.9% of the total area (49,057 hectares) covered by forest. Considering the role of forest effect on the catchment rehabilitation, change in precipitation regime and improved infiltration capacity of the soil, the presence of water body (101 hectares) in present time might be attributed to a significant forest cover change. Thus, the forest cover in the study area facilitates rainwater to percolate in the soil to maintain the water table and come out to the surface in the form of spring and small ponds. The afforestation program by KKL at the beginning of the 20th century and its strategic mission of improving the development and management of community forests in and near urban areas (Brand et al., 2008), has a significant role in present periods forest cover change in the study area.

The second highest positive increment in land cover change between the years observed in built-up in the study area. It changed from 258 hectares in PEF to 8,506 hectares with a total percentage difference of +16.81. Its change is mainly at the expense of open land (55.0%), scrubland (23.2%) and agricultural land (16.7%) (Table 7). High expansion and concentration of built-up area observed in the eastern part of the area (Fig 3b). A significant change in open space (-45.5%) and scrubland (-17.6%) were also observed. Only 181 hectares out of the total 258 hectares of built-up area in PEF remain the same in present time (Table 7). This is mainly attributed to the abandonment of some of the villages in the study area.

Table 7 Land cover confusion Matrix Jerusalem Metropolitan area

Land Cover Category		***Present***														
		AL	**%**	**BU**	**%**	**FL**	**%**	**OS**	**%**	**SL**	**%**	**WB**	**%**	**WL**	**%**	**Grand Total**
PEF	**AL**	267	4.2	1419	16.7	1051	6.3	673	9.3	406	9.8	20	20	522	8.5	**4358**
	BU	0	0.0	181	2.1	31	0.2	33	0.5	8	0.2	0	0	4	0.1	**258**
	OS	5505	87.1	4677	55.0	8328	50.1	4659	64.3	2671	64.2	80	80	3626	59.3	**29547**
	SL	452	7.1	1976	23.2	6197	37.3	1630	22.5	868	20.9	0	0	1643	26.9	**12766**
	WL	100	1.6	253	3.0	999	6.0	252	3.5	204	4.9	0	0	320	5.2	**2129**
	Grand Total	**6324**	**100.0**	**8506**	**100.0**	**16606**	**100.0**	**7247**	**100.0**	**4158**	**100.0**	**101**	**100**	**6117**	**100.0**	**49057**

AL= Agricultural Land, BU= Built-up, FL=Forest Land; SL=Scrubland, WB= Water Body, WL=Woodland

4.2.3. Land cover transformation and proximity effect

In this study, for each land cover categories neighbor analysis were carried out to examine which land cover category is in proximity with or share a boundary. As indicated in table 8, 2.4 kilometers of forest land edge was in proximity with agricultural land Haifa metropolitan area in the past. The highest edge share observed was woodland with agriculture land which was 55.6 kilometers edge share. This might be one reason for the significant decline in woodland cover in the past (Table 4).

In the present period, the highest edge share was between forest land and built-up which was189.5 kilometers. Forest land also had 117.9 kilometers edge share with agricultural land (Table 8). In this context, the forest cover in the present condition might face a serious effect from agricultural land and built-up expansion driven by ever-increasing development demand of the population. Woodland also has the second highest edge share with agricultural land and built-up following the forest land in the present day. It shares edge length of 80.2 kilometers with agricultural land and 52.8 with built up.

Table 8 Neighbor Land cover (Length in Kilometers) Haifa

	PEF		PRESENT	
Land Cover Category	**Agricultural Land**	**Built Up**	**Agricultural Land**	**Built Up**
Forest Land	2.4	0.2	117.9	189.5
Scrubland	19.1	3.4	38.1	28.7
Woodland	55.6	8.5	80.2	52.8

In Jerusalem area, there was no forest in PEF. However, in the present period forest land has the highest edge share with both built-up and agricultural land. Which might be a risk factor for the existing forest in the future especially in such densely populated metropolitan areas where there is a high demand for development and expansion. Forest land was shared 147.3 kilometers with built-up and 122.7 kilometers with agricultural land. In PEF, built-up had the smallest edge length (0.3 kilometers) share with woodland while in the present period built-up had the second highest edge length (98.8 kilometers) share with woodland (Table 9).

Table 9 Neighbor Land cover (Length in Kilometers) Jerusalem

	PEF		PRESENT	
Land Cover Category	**Agricultural Land**	**Built Up**	**Agricultural Land**	**Built Up**
Forest Land	0.0	0.0	122.7	147.3
Scrubland	44.4	6.6	36.7	22.8
Woodland	6.8	0.3	70.1	98.8

4.2.4. Land cover transformation and slope effect

In this study land cover category of the respective periods were analyzed and observed with respect to slope classes. The slope of the study area ranges from 0-47 degrees (Haifa area) and 0-63 degrees (Jerusalem area). The slope was classified into six classes as indicated in Appendix 2. The area coverage of the land cover classes across six slope classes in two periods were presented in Fig 4a and 4b. Almost all the land cover types were found in the five slope classes of the studied area with different proportions.

In Haifa, woodland was the dominant followed by open space and scrubland in the past while in present, forest land and open space were the dominant land covers (Fig 4a). Built-up recorded the lowest area in both periods. Moreover, in the present period, agricultural land was also recorded the lowest area in this slope class. Similarly, in the slope class of 6-9 woodland and open space was the dominant land cover types followed by scrubland in PEF. Built-up and agricultural land was the dominant one in the present period. On the contrary, built-up recorded the lowest area in this slope class. Woodland, open space, scrubland, and forest land were the dominant land cover type in slope class 10-15 in PEF accordingly. In the same slope class, forest and woodland were the dominant covers in the present period. In this slope class, the lowest recorded area was for built-up in PEF while scrubland has the lowest record in the present period. In slope class 31-45 built-up was recorded the dominant land cover in the present period. Of the total area, 44755 hectares, the dominant area coverage for land cover were recorded in three slope classes (6-9, 10-15, 16-30 degrees) in PEF and four slope classes (1-9, 10-15, 16-30, 31-45 degrees) in the present period.

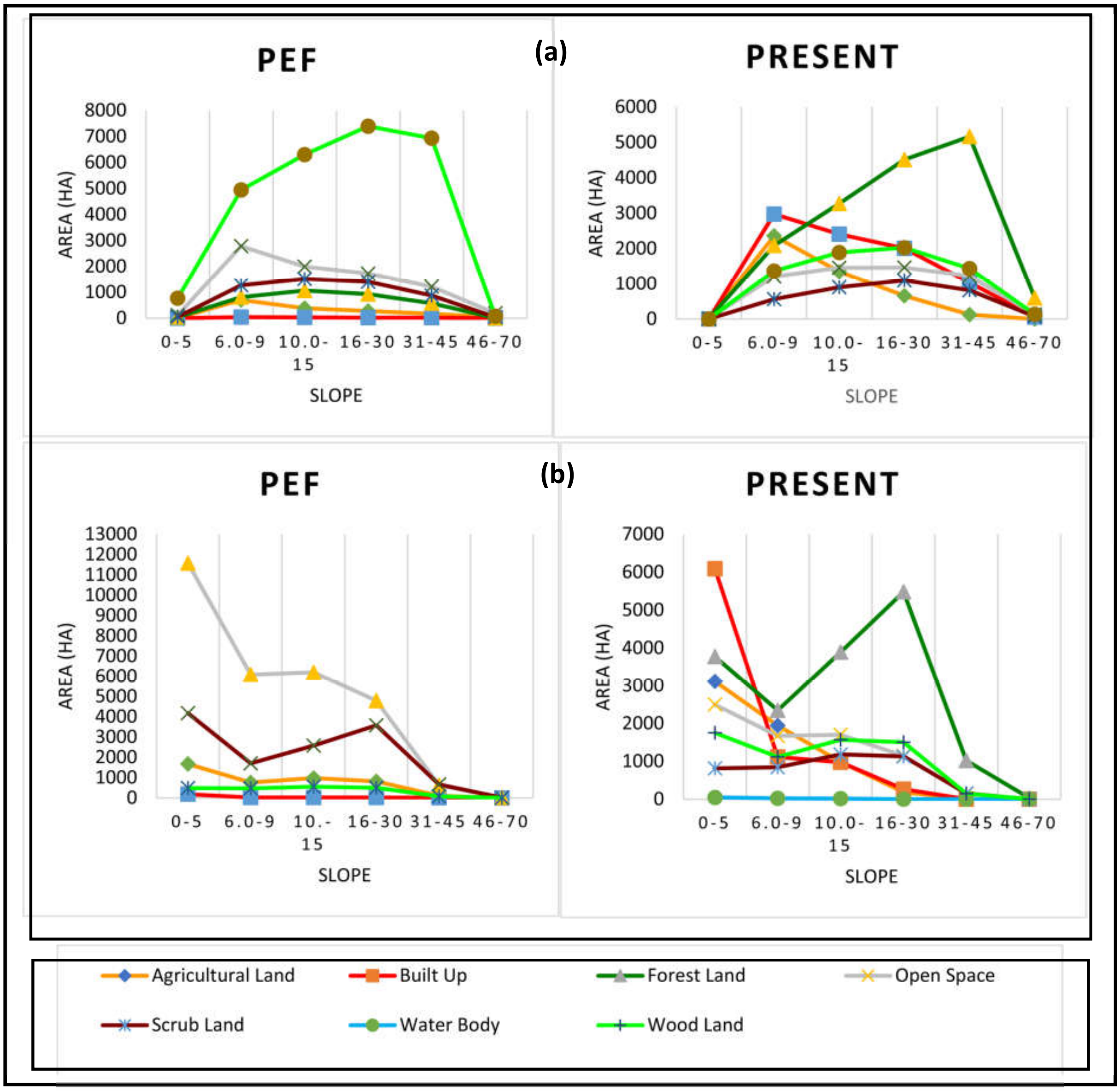


Figure 4 Spatial distribution of land cover across slope classes (Haifa (a) and Jerusalem (b))

As indicated in Fig 4b, scrubland and open space were the dominant land cover types across all slope classes in PEF. For the same period, the lowest area was recorded in the built-up across all the slope classes in Jerusalem area. Slope class 0-5 and 10-15 has the highest record in total area coverage for the land cover of all slope classes in PEF. On the other hand, in the present period, forest land was recorded the dominant land cover in all slope classes except 0-5 class. In slope class, 0-5 degrees built up was the dominant followed by forest land. In all slope classes, water body recorded the lowest area coverage. Relatively, the built-up area shows a decreasing trend with an increasing slope on the contrary forest land shows an increasing trend.

4.3. Land cover fragmentation

The result showed a dynamic temporal trend in land cover fragmentation (Tables 10 and 11). Patch number was relatively higher in the present period. However, a proportional increment in area coverage was also observed between the periods in agricultural land, built up and forest land. An analysis of the percentage of landscape (PLAND) and edge density (ED) parameters in Haifa area, showed that built up had the lowest number compared to the rest of the land cover categories for both periods. Woodland in PEF and forest land in the present period had the highest PLAND (Table 10). Similarly, the highest edge density value was observed in woodland and forest land in PEF and present period, respectively (Fig 5).

Table 10 Landscape metrics for Haifa metropolitan area

	LC category	CA	NP	PLAND	PD	ED	LPI	LSI	AREA_MN	PARA_MN	IJI
PEF	AL	1567.71	38	3.50	0.08	3.08	0.80	9.61	41.26	160.85	70.14
	BU	104.94	22	0.23	0.05	0.49	0.05	5.64	4.77	303.86	75.09
	FL	3435.93	6	7.68	0.01	1.68	6.30	3.38	572.66	74.01	73.87
	OS	8031.78	61	17.95	0.14	8.11	6.40	12.44	131.67	186.78	67.41
	SL	5169.60	30	11.55	0.07	6.44	3.10	10.72	172.32	255.40	69.79
	WL	26444.70	18	59.09	0.04	11.17	48.00	8.17	1469.15	191.71	78.55
Present	AL	4623.12	120	10.33	0.27	9.37	2.20	17.62	38.53	393.10	94.42
	BU	8575.11	302	19.16	0.67	12.52	7.91	16.19	28.39	865.79	87.61
	FL	15744.42	163	35.18	0.36	26.51	13.85	23.93	96.59	391.35	96.26
	OS	5491.89	401	12.27	0.90	18.83	0.88	29.24	13.70	588.85	88.70
	SL	3456.54	109	7.72	0.24	8.45	1.04	16.35	31.71	322.82	91.67
	WL	6863.40	128	15.34	0.29	16.75	2.31	22.81	53.62	294.71	86.85

In addition, patch number was higher in open space followed by agricultural land and scrubland in PEF while the least patch number was in forest land. The highest patch number in the present period was in open space followed by built-up and forest land whereas least was in scrubland. The least patch index (LPI) was observed in built-up, while woodland had the highest values in PEF. In present forest land had the highest LPI. Built-up had also the highest PARA compared to the remaining category (Table 10).

The result also showed spatial variation in fragmentation. A greater probability of dispersion in the forest land and woodland categories was observed. The Interspersion Juxtaposition Index (IJI) ranged between 0 (for clumped patches) and 100 (Open Space/grassland). Woodland in PEF and forest land in the present day had the highest

IJI. Furthermore, results indicated the largest mean patch area in woodland and forest land woodland in PEF and present period, respectively (Fig 5).

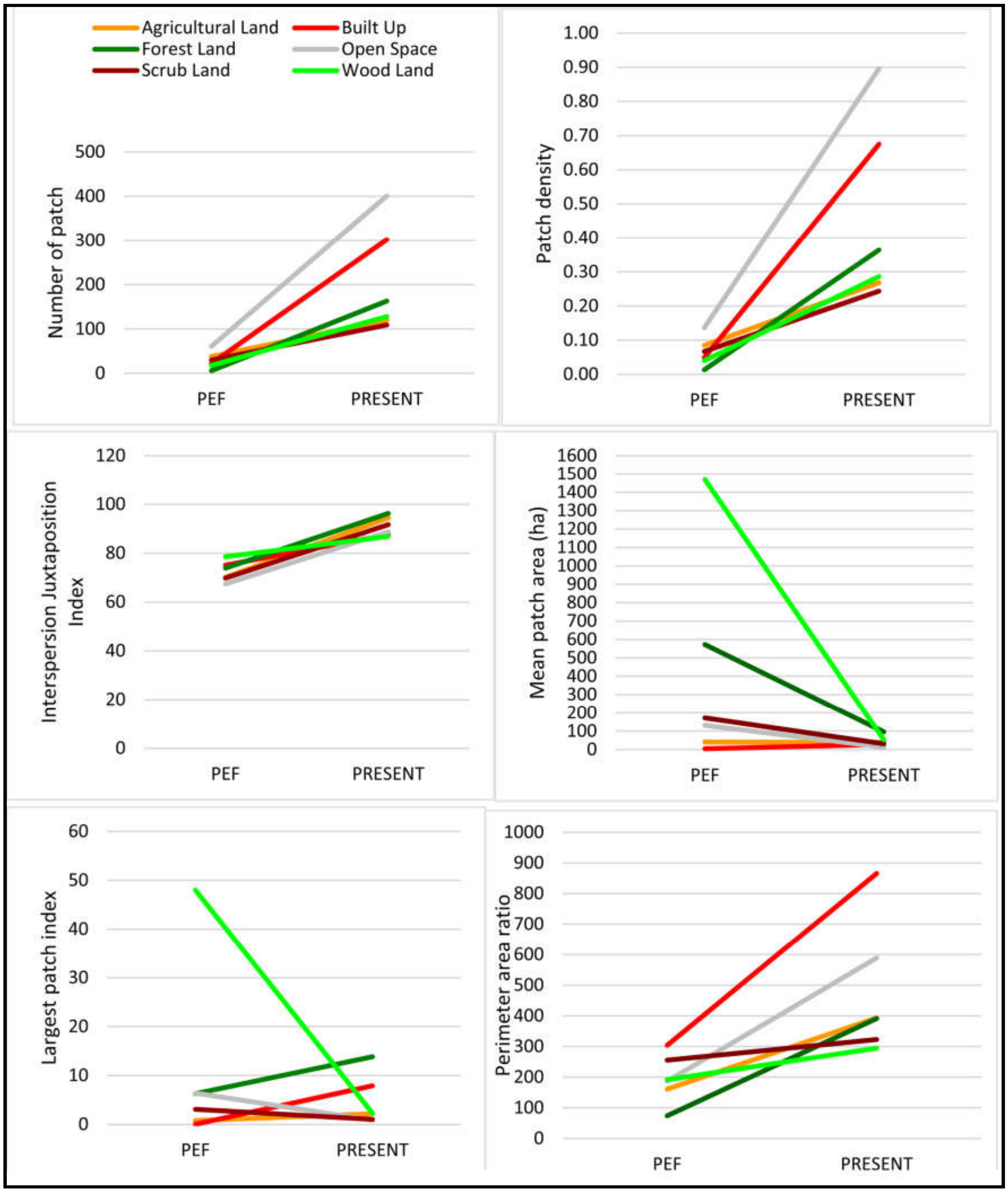


Figure 5 Spatial variability in the six fragmentation indices in Haifa

In Jerusalem, scrubland has the highest number of patches in PEF whereas woodland had the least. Built-up has the least PLAND and ED compared to the rest of the land cover categories in PEF. The least Large patch index (LPI) was observed in built-up, while open space had the highest values in PEF. In present, forest land had the highest LPI. Built-up had also the highest PARA in both periods (Table 11).

Table 11 Landscape metrics for Jerusalem metropolitan area

	TYPE	CA	NP	PLAND	PD	LPI	ED	LSI	AREA_MN	PARA_MN	IJI
PEF	AL	4360.2	56	8.9	0.11	1.0	5.8	11.1	77.9	122.9	49.9
	BU	257.4	42	0.5	0.09	0.3	0.8	6.3	6.1	283.0	61.2
	OS	29540.4	15	60.2	0.03	54.4	13.7	11.4	1969.4	173.8	72.8
	SL	12767.9	64	26.0	0.13	13.3	9.7	11.0	199.5	111.6	47.9
	WL	2130.4	12	4.3	0.02	1.0	1.8	5.4	177.5	69.7	66.2
Present	AL	6329.5	106	12.9	0.22	7.6	10.5	17.5	59.7	380.6	89.5
	BU	8505.8	248	17.3	0.51	8.1	12.8	17.6	34.3	614.0	80.4
	FL	16608.6	144	33.9	0.29	28.7	18.1	17.7	115.3	396.7	82.7
	OS	7243.9	367	14.8	0.75	2.0	21.2	31.7	19.7	455.4	85.3
	SL	4154.0	79	8.5	0.16	2.2	7.6	14.9	52.6	253.2	83.6
	WB	101.3	7	0.2	0.01	0.1	0.3	4.5	14.5	293.0	46.7
	WL	6113.1	122	12.5	0.25	2.0	11.9	18.9	50.1	372.4	87.8

In Jerusalem area, a greater probability of dispersion in the woodland and open space cover were observed. In PEF, like that of Haifa metropolitan area, in Jerusalem, the woodland had the highest IJI. Agricultural land also had the highest IJI in the present period. Furthermore, results indicated the highest parameter area ratio in built-up in both PEF and present period (Fig 6).

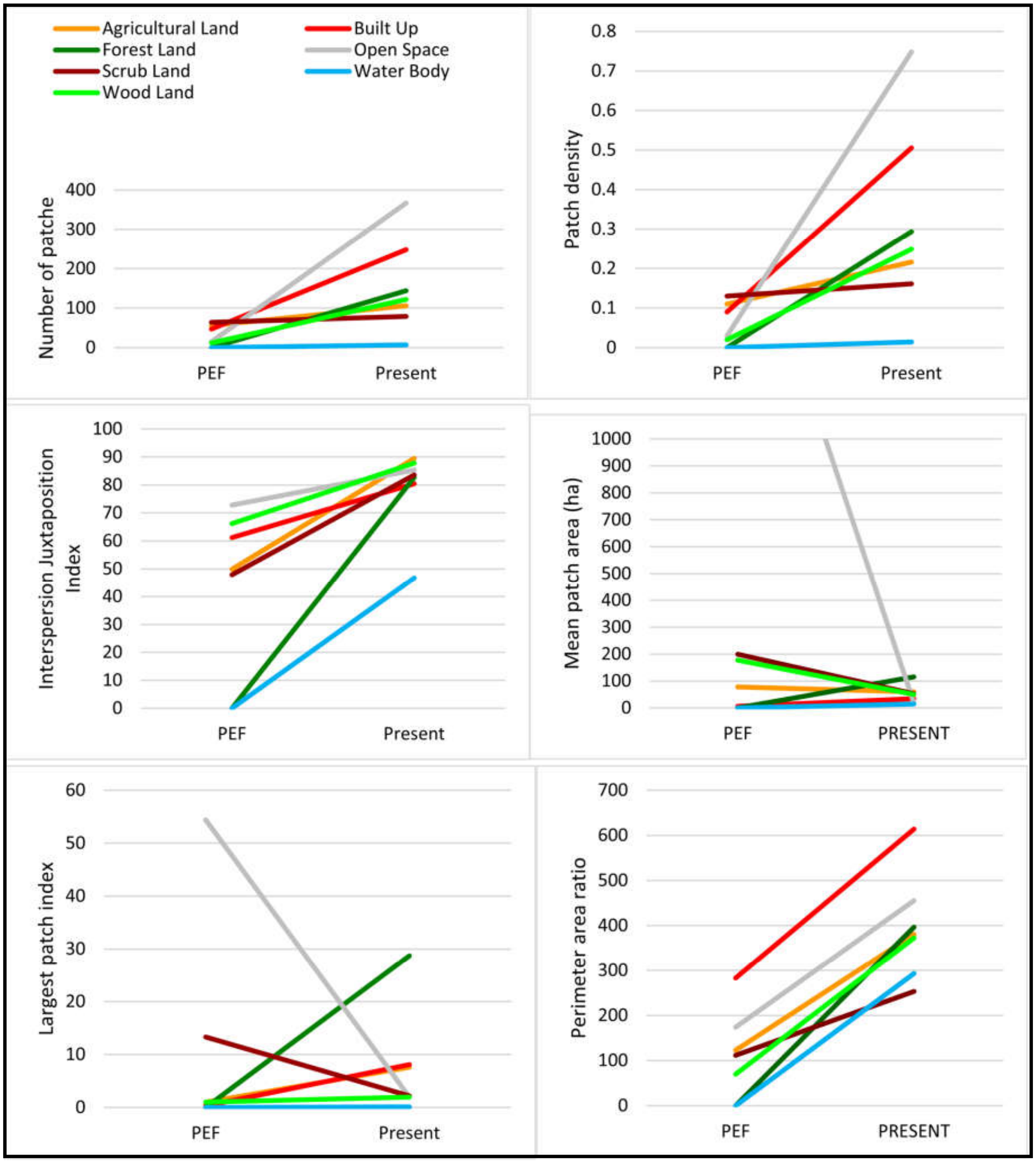


Figure 6 Spatial variability in the six fragmentation indices in Jerusalem

5. DISCUSSION

5.1. Land cover classification in 1881 and 2019

This study assessed land cover classes in the studied area by integrating GIS and remote sensing techniques. The basis of this research comprises a historical map (PEF) and satellite image of the present day (2019) to classify and map land cover between 1881and 2019. Based on the analysis of the historical map and the image as an input data, generally, about six land cover classes were identified in Haifa metropolitan area. These include agricultural land, built-up, forest land, open space, scrubland, and woodland. Woodland was the dominant land cover in the past while in the present day, forest land was the dominant land cover than other categories in Haifa area.

In Jerusalem, the classification and mapping result identified agricultural land, built-up, open space, scrubland and woodland in the past. On the other hand, in the present day, forest land and water body identified in addition to what has been already identified in the past. Forest land and water body were absent in the past. In the present day, forest land is the dominant land cover in Jerusalem metropolitan area.

5.2. Land cover transformation (1981-2019)

The study result showed a substantial decline in woodland in Haifa metropolitan area. This can be a direct reflection of the dynamics of socioeconomic development in the area. Several factors stimulated by the activity of man are responsible for massive conversion of woodland cover. For instance, about 20.5% of woodland was converted to Built-up and agricultural land that are directly or indirectly related to population growth and their development needs. Likewise, It has also been stated by many authors that land cover changes are driven by socioeconomic factors (deforestation, agricultural land expansion, settlement, road construction, etc) (Alganci, 2019; Boriah et al., 2010). Braverman (2015), also reported that the relationship between human and the vegetation in Israel has been out of balance and it might be the reason for the observed change. Furthermore, tree cuttings in woodland and forest ecosystem of Israel for glass factory, iron industry and to operate the Ottoman steam trains and for the war efforts (Bone & Harel, 2015; Neeman, 1993), were also reported that might contribute for the significant reduction in woodland.

The result also shows the substantial increment in forest cover in both studied areas. The increase of forest cover in Israel was already reported by Schaffer & Levin (2014). The positively significant forest cover change with time in the studied areas is attributed to the fact that massive afforestation by KKL/JNF which are undergoing since its establishment of the state of Israel in 1948 (Braverman, 2015). Massive national program to reclaim and restore Israel’s degraded Mediterranean landscape in the coastal plain and valleys also has a significant role in increasing forest cover in the studied areas over time (Brand et al., 2008). According to Ritz Finkelstein (2014), in Haifa and Jerusalem, modern tree planting effort began in 1980 with a group of German Templars who emigrated to Ottoman-ruled Palestine (Current day Israel). They planted cypress and pine along the main streets of Haifa and Jerusalem. Though their effort was not enormous in scale, were the important initial point for change in forest cover over time.

In the present period, woodland also shows increment trend with time in Jerusalem area. Also, we could observe a woodland augmentation in the present period which was at the expense of open space and scrubland. Similarly, Yom-Tov, et al. (2012), pointed out the augmentation of wooded areas since the beginning of the 20th century as a result of the extensive gardening. On the contrary, scrubland shows a decreasing trend in both studied areas. Mainly, the highest percentage cover of scrubland in the studied area was converted to agricultural land and built-up. A similar trend of reduction in scrubland was reported by Schaffer & Levin (2014). The decline in scrubland area with time might reduce the uniqueness of the landscape which is dominated by vegetation characterized by the Mediterranean climate and possibly reduce the biological diversity. Ritz Finkelstein (2014), reported the scrubland (shrub steppe) is becoming rare in the Israeli landscape and plants associated with this land cover listed as endangered (Amit and Avi, 2004). Similarly, Sala et al. (2000), in their study made in the French Mediterranean region, biological diversity was threatened by the land cover change were reported.

At the present period, the land cover category which has increased the most was built-up in both studied areas. Agricultural expansion and built-up development were driven by the ever-increasing population and demand for residential land are apparent in the studied area. As a result, at present period forest ecosystems and natural vegetation covers are under pressure. Likewise, Václavík & Rogan (2009), in identifying the trends in land cover changes in the context of post-socialist transformation in central Europe reported a significant conversion of coniferous forest into built-up uses between the year 1991 and 2001. In addition, intensification of agricultural activity in Portugal (Godinho et al., 2016) and Spain (Serra, Pons, & Saurí, 2008), were also noted as a challenge for the alteration vegetation cover.

The neighbor analysis showed the highest edge share for forest land, scrubland and woodland with built-up and agriculture land in the present day than the past in both studied areas. In this context, the forest cover in proximity with built-up in the present day in both studied areas might face a serious effect from expansion and development activities. Woodland also has the second highest edge share/proximity with agricultural land and built-up following the forest land. Consequently, this might be a risk factor for the existing woodland in the future especially in such densely populated metropolitan areas where there is substantial demand for development and expansion. Most empirical data on the effect of built-upon natural land covers (forest, woodland, scrubland, etc) also noted that the built-up proximity to natural vegetation and its traffic have a significant effect through disturbance or edge effects (Laurance et al., 2015). Disturbance or edge effects also result from the pollution of the physical, chemical and biological environment as a result of infrastructure construction and farming operation. Thus, mainly it affects the vegetation cover and natural landscape.

5.3. Land cover fragmentation

The negative trend in land cover area for woodland and scrubland was prevalent in Haifa while the negative trend in Jerusalem was observed in scrubland. Negative trend patterns in the extent of total land cover area coverage have close relations with deleterious fragmentation effects (Cushman, 2006). However, the effects of fragmentation are dependent on land cover size (Fahrig, 2003). Perimeter-area results showed distinct differences with time in the built-up and scrubland patterns. A high perimeter-area relationship characterizes the rapid rate of fragmentation among vegetation covers underlying forest land, woodland, and scrubland. Open space and built-up displays an increase in patch number between past and present. The fragmentation is driven by socioeconomic and demographic reasons (Green et al., 2013).

The highest changes in mean patch area patterns were recorded on woodland and forest land in Haifa, and forest land and woodland in Jerusalem. Furthermore, woodland patch number increased in the studied area. This is an indication of the high fragmentation level in woodland in the studied areas (Jorge & Garcia, 1997). A combination of patch density (PD) and PARA (perimeter to area ratio) are considered profound in the estimation of the extent of fragmentation in each land cover analyzed (Jorge & Garcia, 1997). Patch density and perimeter to area ratio (PARA) have been profound in fragmentation assessments as they have a strong influence on ecosystem functioning and ecological processes. Open space and built-up had the highest patch number over the years, which are attributed to socioeconomic activities and fragmentation of vegetation covers mainly emerging from human activity. Similar findings were explained by dynamics in mean patch area which was driven by pressure from anthropogenic disturbances (Stoms & Estes, 1993).

The interspersion juxtaposition index (IJI), was reflective in characterizing the degree of adjacency for each patch type. Forest land in Haifa and agricultural land in Jerusalem metropolitan area had the highest IJI in the present day. Open space and built-up had a greater patch density, signifying higher spatial heterogeneity. In addition, the largest patch index was associated with forest land in both studied areas in the present day. This indicates the fragmented nature of forest land. Furthermore, forest land and woodland had the largest edge density in Haifa while in Jerusalem, forest land had the largest edge density. This is attributed to increased exposure to built-up and agriculture land. Edge effects characterize the biophysical state of ecosystems at the periphery or in the neighborhood and have deleterious effects in the long term. This is because the disintegration of land cover intensifies the response of abiotic edge effects on ecosystem functioning (Harper et al., 2005) and reduces vegetation covers ability to sustain a population (Fahrig, 2003). Other similar studies established a great intensity of fragmentation associated with more edge effects through the exposure of contiguous vegetation cover to solar radiation and soil moisture to drier heat conditions (Csorba et al., 2012).

6. CONCLUSIONS

The results of the study revealed that the land cover of the studied area, as depicted by changes in land cover mapping, has changed dramatically since 1881 in the studied areas. The land cover classes which increased positively were forest land and human-dominated land covers such as built-up and agricultural land. The land cover change detection analysis also disclosed the change in land cover in the form of conversion. Thus, the findings of the land cover analysis have paramount importance for the management of the natural resource by using as an input for the land use plan at the landscape level. Formulating a land use plan using these results will facilitate optimum resource allocation and implementing of mitigation measures for each local development activity.

The study conducted has shown that land cover in both studied areas increasingly threatened by rapid infrastructure development and expansion. Land cover especially vegetation covers, as explained by neighbor analysis, were in proximity and share longest edge length with built-up and agricultural land. This can be a potential threat for forest land, scrubland, and woodland in the studied area. Built-up expansion is a threat because it consumes areas: i.e. infrastructure construction may be a stronger threat than the qualitative change due to irreversible land cover change, and the resulting potential impacts must not be neglected. Hence, we call attention not only to infrastructure development but also to problems associated with urban forest interfaces, whose extent we feel is likely to increase in both studied areas.

The result showed a dynamic temporal and spatial variation trend in land cover fragmentation. Distinct differences in magnitude are evident for each land cover category analyzed. The magnitude of fragmentation was significant in woodland. One important aspect which stands out from the study is that fragmentation seems to be driven by socioeconomic development need of the growing population in the studied areas. Generally, this study provides important knowledge on spatiotemporal land cover patterns in the studied areas and each of the results has a fundamental role to play on planning conservation works that aim to protect fragile land covers which are subjected to anthropogenic disturbances in the studied areas.

7. ACKNOWLEDGMENTS

8. REFERENCES

Addae, B., & Oppelt, N. (2019). Land-Use/Land-Cover Change Analysis and Urban Growth Modelling in the Greater Accra Metropolitan Area (GAMA), Ghana. *Urban Science*, *3*(1), 26. https://doi.org/10.3390/urbansci3010026

Avi, D. A. and P. (2004). *The Red Book: vertebrates in Israel*. Jerusalem: Israel Nature and Parks Authority ; Society for the Protection of Nature in Israel, 2004.

Baker, W. L. (1989). A review of models of landscape change. *Landscape Ecology*. https://doi.org/10.1007/BF00137155

Bar Massada, A., Carmel, Y., Koniak, G., & Noy-Meir, I. (2009). The effects of disturbance based management on the dynamics of Mediterranean vegetation: A hierarchical and spatially explicit modeling approach. *Ecological Modelling*. https://doi.org/10.1016/j.ecolmodel.2009.06.002

Bone, O., & Harel, R. (2015). The Sharon's Tabor oak forest is alive and kicking. *Yaar [Hebrew]*, (15), 64–71.

Brand, D., Moshe, I., Shaler, M., Zuk, A., Kayemeth, K., & Fund, L. N. (2008). Afforestation in Israel – reclaiming ecosystems and combating desertification, *1998*, 1–4.

Braverman, I. (2015). Planting the Promised Landscape: Zionism, Nature, and Resistance in Israel/Palestine, (November).

Burgi, M., Hersperger, A. M., & Schneeberger, N. (2005). Driving forces of landscape change - current and new directions. *Landscape Ecology*, *19*(8), 857–868. https://doi.org/10.1007/s10980-005-0245-3

Conway, T. M., & Lathrop, R. G. (2005). Alternative land use regulations and environmental impacts: Assessing future land use in an urbanizing watershed. *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2003.08.005

Csorba, P., Szabo, S., Grose, M. J., Haines-Young, R., Chopping, M., Rutledge, D., … Metzger, J. P. (2012). Landscape indices as measures of the effects of fragmentation: can pattern reflect process? *Natureza a Conservacao*. https://doi.org/10.5772/36182

Cushman, S. A. (2006). Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological Conservation*, *128*(2), 231–240. https://doi.org/10.1016/j.biocon.2005.09.031

Cushman, S. A., Shirk, A., & Landguth, E. L. (2012). Separating the effects of habitat area, fragmentation and matrix resistance on genetic differentiation in complex landscapes. *Landscape Ecology*, *27*(3), 369–380. https://doi.org/10.1007/s10980-011-9693-0

Dale, V. H., Brown, S., Haeuber, R. A., Hobbs, N. T., Huntly, N., Naiman, R. J., … Valone, T. J. (2000). Ecological principles and guidelines for managing the use of land. *Ecological Applications*.

Dale, Virginia H, O'Neill, R. V, Pedlowski, M., & Southworth, F. (1993). Causes and effects of land-use change in central Rondonia, Brazil. *Photogrammetric Engineering and Remote Sensing*.

Danin, A. (1991). Flora and vegetation of Israel and adjacent areas, (Table I), 18–42.

Debussche, M., Lepart, J., & Dervieux, A. (1999). Mediterranean landscape changes: Evidence from old postcards. *Global Ecology and Biogeography*. https://doi.org/10.1046/j.1365-2699.1999.00316.x

Dumas, E., Jappiot, M., & Tatoni, T. (2008). Mediterranean urban-forest interface classification (MUFIC): A quantitative method combining SPOT5 imagery and landscape ecology indices. *Landscape and Urban Planning*, *84*(3–4), 183–190. https://doi.org/10.1016/j.landurbplan.2007.12.002

Fahrig, L. (2003). Effects of Habitat Fragmentation on Biodiversity. *Annual Review of Ecology, Evolution, and Systematics*. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Flather, & Bevers. (2017). Patchy Reaction-Diffusion and Population Abundance: The Relative Importance of Habitat Amount and Arrangement. *The American Naturalist*. https://doi.org/10.2307/3079313

Geist, H., McConnell, W., Lambin, E. F., Moran, E., Alves, D., & Rudel, T. (n.d.). Causes and Trajectories of Land-Use/Cover Change. In *Land-Use and Land-Cover Change*. https://doi.org/10.1007/3-540-32202-7_3

Green, J. M. H., Larrosa, C., Burgess, N. D., Balmford, A., Johnston, A., Mbilinyi, B. P., … Coad, L. (2013). Deforestation in an African biodiversity hotspot: Extent, variation and the effectiveness of protected areas. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2013.04.016

Grohmann, C. H. (2004). Morphometric analysis in geographic information systems: Applications of free software GRASS and R. *Computers and Geosciences*. https://doi.org/10.1016/j.cageo.2004.08.002

Harel, M. (1974). Gi-Harshim [Hebrew]. *Merchavim*, (1), 49–62.

Harper, K. A., Macdonald, S. E., Burton, P. J., Chen, J., Brosofske, K. D., Saunders, S. C., … Esseen, P. A. (2005). Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology*. https://doi.org/10.1111/j.1523-1739.2005.00045.x

https://geographyfieldwork.com. (2018). Slope Steepness Index: Barcelona Field Studies Center. Retrieved June 20, 2019, from https://geographyfieldwork.com/SlopeSteepnessIndex.htm

Israel Minstry of Foreign Affairs. (2013). THE LAND: Geography and Climate. Retrieved June 2, 2019, from https://mfa.gov.il/mfa/aboutisrael/land/pages/the land- geography and climate.aspx

Jewish Virtual Library. (n.d.). Israeli Ministry of Tourism. Retrieved June 13, 2019, from https://www.jewishvirtuallibrary.org/israeli-ministry-of-tourism

Jorge, L. A. B., & Garcia, G. J. (1997). A study of habitat fragmentation in Southeastern Brazil using remote sensing and geographic information systems (GIS). *Forest Ecology and Management*. https://doi.org/10.1016/S0378-1127(97)00072-8

Kaplan, M. (2011). *National Outline Plan for Forests and Afforestation NOP 22 Policy Document*. (J. Woodcock, Ed.). Jerusalem: Maor Wallach Ltd.

Karmon, Y. (1959). The physiological conditions of the Sharon and their influence on the development of the settlements [Hebrew], *40–41*, 137–160.

Kleemann, J., Baysal, G., Bulley, H. N. N., & Fürst, C. (2017). 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*. https://doi.org/10.1016/j.jenvman.2017.01.053

Kong, F., & Nakagoshi, N. (2006). Spatial-temporal gradient analysis of urban green spaces in Jinan, China. *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2005.07.006

Lambin, E. F. (1997). Modelling and monitoring land-cover change processes in tropical regions.

Progress in Physical Geography. https://doi.org/10.1177/030913339702100303

Lambin, E. F., & Geist, H. J. (2011). Causes of Land Use and Land Use Cover Change. *National Council for Science and the Environment*, (March), 1–8. https://doi.org/10.1109/MWSYM.2011.5973575

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., … Xu, J. (2001). The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change*. https://doi.org/10.1016/S0959-3780(01)00007-3

Laurance, W. F., & Balmford, A. (2013). Land use: A global map for road building. *Nature*, *495*(7441), 308–309. https://doi.org/10.1038/495308a

Laurance, W. F., Peletier-Jellema, A., Geenen, B., Koster, H., Verweij, P., Van Dijck, P., … Van Kuijk, M. (2015). Reducing the global environmental impacts of rapid infrastructure expansion. *Current Biology*, *25*(7), R259–R262. https://doi.org/10.1016/j.cub.2015.02.050

Levin, N. (2006). The Palestine Exploration Fund Map (1871–1877) of the Holy Land as a Tool for Analysing Landscape Changes: the Coastal Dunes of Israel as a Case Study. *The Cartographic Journal*. https://doi.org/10.1179/000870406x93508

Lillesand, T., Kiefer, R., & Chipman, J. (2015). *Remote sensing and image interpretation Seventh Ed. John Wiley and Sons, Inc., New York*.

McGarigal, K., SA Cushman, and E. E. (2012). FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program. University of Massachusetts, Amherst. Retrieved from http://www.umass.edu/landeco/research/fragstats/fragstats.html

McGarigal, K., & J., M. B. (1995). *FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure*.

McNeill, J., Alves, D., Arizpe, L., Bykova, O., Galvin, K., Kelmelis, J., & Riebsame, W. (1994). Toward a typology and regionalization of land-cover and land use change: Report of working Group B. In *Changes in land use and land cover: A global perspective*.

Médail, F., & Quézel, P. (1999). Biodiversity Hotspots in the Mediterranean Basin : Setting Global Conservation Priorities, *13*(6), 1510–1513.

Millington, A. C., Velez-Liendo, X. M., & Bradley, A. V. (2003). Scale dependence in multitemporal mapping of forest fragmentation in Bolivia: Implications for explaining temporal trends in landscape ecology and applications to biodiversity conservation. *ISPRS Journal of Photogrammetry and Remote Sensing*, *57*(4), 289–299. https://doi.org/10.1016/S0924-2716(02)00154-5

NASA Jet Propulsion Laboratory: California Institute of Technology. (2004). ASTER Global Digital Elevation Map. Retrieved June 20, 2019, from https://asterweb.jpl.nasa.gov/gdem.asp

Neeman, Y. (1993). The glass manufacturing plant in Hadera during the Byzantine period [Hebrew]. *Ariel*, *95–96*, 9–16.

Oppenheimer, C. (1999). W ILKIE , D. S. & F INN , J. T. 1996. Remote Sensing Imagery for Natural Resources Monitoring. A Guide for First-Time Users . Methods and Cases in Conservation Science Series. xxi + 295 pp. New York, Chichester: Columbia University Press. Price £40.00 (h. *Geological Magazine*. https://doi.org/10.1017/s0016756899252363

Pal, S., & Ziaul, S. (2017). Detection of land use and land cover change and land surface temperature in English Bazar urban centre. *Egyptian Journal of Remote Sensing and Space Science*, *20*(1), 125–145. https://doi.org/10.1016/j.ejrs.2016.11.003

Perz, S., Brilhante, S., Brown, F., Caldas, M., Ikeda, S., Mendoza, E., … Walker, R. (2008). Road building, land use and climate change: Prospects for environmental governance in the Amazon. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1498), 1889–1895. https://doi.org/10.1098/rstb.2007.0017

Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Nilon, C. H., Pouyat, R. V., Zipperer, W. . C., & Costanza, R. (2001). Urban Ecological Sysytems : Linking Terrestrial Ecological , Physical , and Socioeconomic of Metropolitan Areas. *Annual Review of Ecology and Systematics*. https://doi.org/doi:10.1146/annurev.ecolsys.32.081501.114012

Pickett, S. T. A., & McDonnell, M. J. (2011). Human as Components of Ecosystems: A Synthesis. In *Humans as Components of Ecosystems*. https://doi.org/10.1007/978-1-4612-0905-8_24

Ritz Finkelstein, A. (2014). Assessing a National Experiment in Drylands Afforestation THE NATURE OF THE NEGEV, (December).

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., … Wall, D. H. (2000). Global biodiversity scenarios for the year 2100. *Science*. https://doi.org/10.1126/science.287.5459.1770

Schaffer, G., & Levin, N. (2014). Mapping human induced landscape changes in Israel between the end of the 19Th century and the beginning of the 21Th century. *Journal of Landscape Ecology(Czech Republic)*. https://doi.org/10.2478/jlecol-2014-0012

Seiler, A. (2015). *European Co-operation in the Field of Scientific and Technical Research COST Action 341 Habitat Fragmentation due to Transportation Infrastructure The European review*.

Stéphenne, N., & Lambin, E. F. (2001). A dynamic simulation model of land-use changes in Sudano-sahelian countries of Africa (SALU). *Agriculture, Ecosystems and Environment*. https://doi.org/10.1016/S0167-8809(01)00181-5

Stoms, D. M., & Estes, J. E. (1993). A remote sensing research agenda for mapping and monitoring biodiversity. *International Journal of Remote Sensing*. https://doi.org/10.1080/01431169308954007

Tal, A. (2012). Israel's new Bible of forestry and the pursuit of sustainable dryland afforestation. *Geography Research Forum*, *32*(January 2012), 81–95.

Thomlinson, J. R., & Rivera, L. Y. (2000). Suburban growth in Luquillo, Puerto Rico: Some consequences of development on natural and semi-natural systems. *Landscape and Urban Planning*. https://doi.org/10.1016/S0169-2046(00)00056-6

United Nations. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. *World Population Prospects*. https://doi.org/10.1017/CBO9781107415324.004

Vogelmann, J. E. (1995). Assessment of Forest Fragmentation in Southern New England Using Remote Sensing and Geographic Information Systems Technology. *Conservation Biology*, *9*, 439–449.

Wang, Y.-C., & Feng, C.-C. (2008). Visualizing research of land use land cover change. In *Geoinformatics 2008 and Joint Conference on GIS and Built Environment: The Built Environment and Its Dynamics* (Vol. 7144, p. 71440J). https://doi.org/10.1117/12.812709

Wang, Y. C., & Feng, C. C. (2011). Patterns and trends in land-use land-cover change research explored using self-organizing map. *International Journal of Remote Sensing*, *32*(13), 3765–3790. https://doi.org/10.1080/01431161.2010.540590

Willis, K. J. (2001). Mediterranean Europe: a consequence of nature or nurture? *Journal of Biogeography*. https://doi.org/10.1046/j.1365-2699.2001.0610a.x

www.timeanddate.com. (n.d.). Climate & Weather Averages in Jerusalem, Israel. Retrieved

June 13, 2019, from https://www.timeanddate.com/weather/israel/jerusalem/climate

www.timeanddate.com. (2019). Climate & Weather Averages in Haifa, Israel. Retrieved June 13, 2019, from https://www.timeanddate.com/weather/israel/haifa/climate

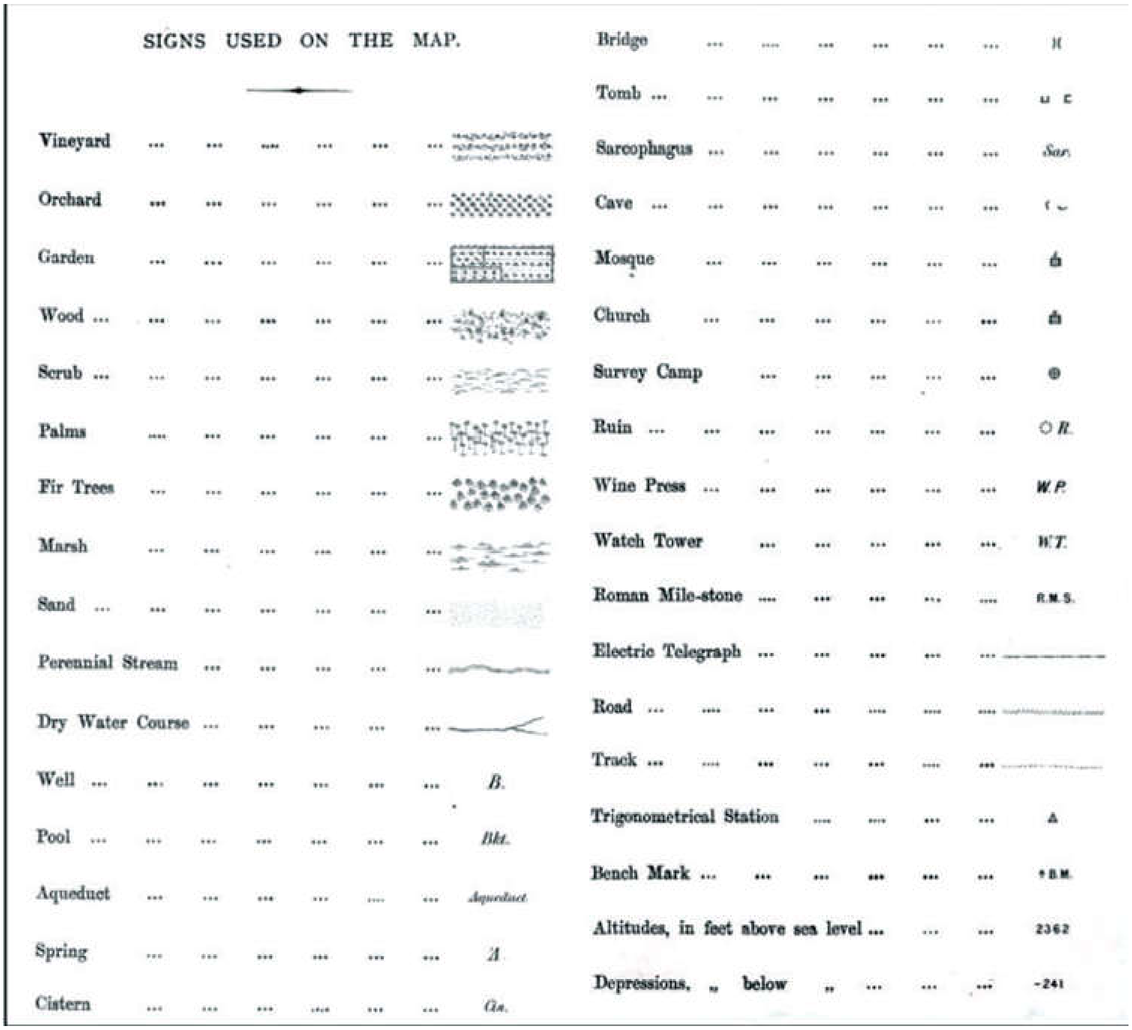
Yom-Tov, Y., Hatzofe, O., & Geffen, E. (2012). Israel's breeding avifauna: A century of dramatic change. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2012.01.005

Zengin, H., Değermenci, A. S., & Bettinger, P. (2018). Analysis of temporal changes in land cover and landscape metrics of a managed forest in the west Black Sea region of northern Turkey: 1970–2010. *Journal of Forestry Research*. https://doi.org/10.1007/s11676-017-0423-6

Zubair, O. (2011). Change detection in land use and land cover using geo-spatial methods : a case study of ilorin, Nigeria, (131025), 52.

APPENDICES

Appendix 1 PEF Legends



Appendix 2 Land cover across slope class

(a)

Land Cover Category	HAIFA PEF														
	0-5	%	6.-9.	%	10.-15	%	16-30	%	31-45	%	46-70	%	No Value	%	Grand Total
Agricultural Land	8	0.9	702	6.6	381	3.4	279	2.4	164	2	31	9.1	0	0.0	**1566**
Built Up	0	0.0	40	0.4	25	0.2	22	0.2	14	0	3	0.8	0	0.0	**104**
Forest Land	43	4.4	816	7.7	1066	9.4	932	7.9	576	6	5	1.5	0	1.1	**3438**
Open Space	117	11.9	2784	26.4	1993	17.7	1728	14.7	1220	12	194	56.6	1	3.4	**8037**
Scrubland	56	5.6	1270	12.0	1519	13.5	1411	12.0	876	9	38	11.1	0	0.0	**5170**
Woodland	763	77.2	4949	46.9	6298	55.8	7395	62.8	6936	71	71	20.9	26	95.4	**26439**
Grand Total	**988**	**100.0**	**10560**	**100.0**	**11283**	**100.0**	**11767**	**100.0**	**9787**	**100**	343	100.0	**27**	**100.0**	44755

(b)

Land Cover Category	HAIFA PRESENT														
	0-5	%	6.-9.	%	10.-15	%	16-30	%	31-45	%	46-70	%	No Value	%	Grand Total
Agricultural Land	0	0.0	2359	22.3	1347	11.9	660	5.6	123	1.3	0	0.0	133	38.7	**4622**
Built Up	0	0.1	2975	28.2	2411	21.4	2005	17.0	1035	10.6	52	5.3	94	27.6	**8573**
Forest Land	13	47.2	2088	19.8	3272	29.0	4516	38.4	5164	52.8	595	60.2	35	10.4	**15683**
Open Space	11	42.0	1205	11.4	1462	13.0	1463	12.4	1219	12.5	135	13.7	56	16.4	**5552**
Scrubland	1	4.4	566	5.4	898	8.0	1095	9.3	812	8.3	72	7.3	9	2.6	**3454**
Woodland	2	6.4	1367	12.9	1892	16.8	2028	17.2	1433	14.6	134	13.5	15	4.4	**6870**
Grand Total	**27**	**100**	**10560**	**100.0**	**11283**	**100.0**	**11767**	**100.0**	**9787**	**100.0**	**988**	**100.0**	**343**	**100.0**	44755

(c)

Land Cover Category	JERUSALEM PEF														
	0-5	%	6.-9.	%	10.-15	%	16-30	%	31-45	%	46-70	%	No Value	%	Grand Total
Agricultural Land	1673	9.2	764	8.4	974	9.4	820	8.4	101	6.9	4	7.8	22	7	**4358**
Built Up	182	1.0	16	0.2	27	0.3	20	0.2	5	0.3	0	0.9	7	2	**258**
Open Space	11581	64.0	6095	67.3	6202	60.0	4800	49.4	622	42.4	20	43.4	227	69	**29547**
Scrubland	4178	23.1	1707	18.8	2573	24.9	3581	36.8	664	45.3	16	33.8	48	14	**12766**
Woodland	484	2.7	480	5.3	555	5.4	502	5.2	74	5.1	6	14.1	26	8	**2129**
Grand Total	**18098**	**100**	**9062**	**100**	**10331**	**100**	**9724**	**100.0**	**1466**	**100.0**	**46**	**100.0**	**331**	**100**	**49057**

(d)

Land Cover Category	JERUSALEM PRESENT														Grand Total
	0-5	**%**	**6.-9.**	**%**	**10.-15**	**%**	**16-30**	**%**	**31-45**	**%**	**46-70**	**%**	**No Value**	**%**	
Agricultural Land	3114	17.2	1941	21.4	986	9.5	187	1.9	1	0.1	0	0.0	95	28.7	**6324**
Built Up	6094	33.7	1115	12.3	977	9.5	266	2.7	3	0.2	0	0.0	51	15.4	**8506**
Forest Land	3777	20.9	2347	25.9	3892	37.7	5481	56.4	1019	69.5	34	73.1	56	16.9	**16606**
Open Space	2498	13.8	1669	18.4	1704	16.5	1148	11.8	140	9.5	7	15.3	82	24.6	**7247**
Scrubland	814	4.5	848	9.4	1184	11.5	1133	11.7	157	10.7	1	2.2	21	6.4	**4158**
Water Body	49	0.3	26	0.3	16	0.2	3	0.0	0	0.0	0	0.0	6	1.8	**101**
Woodland	1752	9.7	1116	12.3	1572	15.2	1505	15.5	147	10.0	4	9.4	20	6.0	**6117**
Grand Total	**18098**	**100**	**9062**	**100**	**10331**	**100**	**9724**	**100**	**1466**	**100**	**46**	**100**	**331**	**100**	**49057**

Appendix 3 Fragmentation indices used in the present study

Fragstats matrix	**Description**
Patch Density (PD)	Number of patches of the corresponding patch type
Largest Patch Index (LPI)	It's an index used to quantify the percentage of total landscape area characterized by the largest patch.
Edge density (ED)	Used to assess edge length per unit area
Patch Number (NP)	It's a measure of the magnitude of fragmentation of patches
Interspersion Juxtaposition Index (IJI)	The index is used in isolating the interspersion of different patch types.
Patch Area (MN)	Refers to the sum, across all patches in the landscape, of the corresponding patch metric values, divided by the total number of patches in (ha).
Perimeter Area Ratio PARA	Refers to the ratio of the patch perimeter (m) to area (m^2).
Total Area (CA)	Refers to the sum of areas (m^2) of all patches for the patch type
Percentage of Landscape (PLAND)	Useful in computing the proportional abundance for each of the patch type across the landscape